GROWTH
IN THE FETAL PERIOD

SCAMMON AND CALKINS

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THE
DEVELOPMENT AND GROWTH
OF THE
EXTERNAL DIMENSIONS OF THE HUMAN BODY IN THE FETAL PERIOD

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PREFACE

Prenatal growth is a subject of unusual interest in various respects. Its practical importance in relation to the medical sciences, especially to obstetrics and pediatrics, is obvious. It has even greater significance in relation to the broader science of biology, including embryology and physical anthropology.

Growth, like other complicated vital phenomena, can be studied most profitably by the genetic method. We must go back to the earlier stages in order to interpret the later. It is furthermore apparent that the simpler descriptive methods hitherto chiefly employed are insufficient for more than a rather superficial study of the fundamental problems of growth. It becomes increasingly evident that research in embryology, as in other natural sciences, requires more extensive use of quantitative methods. The present work represents a fruitful application of these biometric methods in the field of human developmental anatomy.

The most important result of this work is the establishment of a new principle, that in general the linear growth of the various parts of the body is in uniform ratio during the fetal period. This seems at first glance to contradict the well-known fact that the proportions of the various regions change during this period, the lower limbs becoming relatively larger and the head relatively smaller. But the present study demonstrates clearly that these changes in proportion arise, in spite of the constant fetal growth ratios, through inequalities already established in the earlier embryonic period. The newly recognized law of uniform fetal growth ratios is shown to be in complete harmony with the previously known "law of developmental direction."

Other features of importance include the tabulation of extensive data and the determination of exact formulae for the fetal body-length according to age, and for seventy different external dimensions in relation to body-length. The reliability of the measurements was tested both experimentally and statistically. Special studies were made to show also the effects of birth moulding and the artifacts produced by formalin preservation. It is found that the normal course of growth cannot be precisely determined until these common sources of error are eliminated. The wealth of original data and the critical discussion make this an indispensable work of reference to all who are concerned with the problems of growth.

C. M. Jackson

University of Minnesota
Minneapolis, April, 1929

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PART I

THE GENERAL PLAN OF THE INVESTIGATION

I. Introduction

The prenatal portion of the life cycle of the human body may be roughly divided into three main epochs or periods: the period of the ovum, the period of the embryo, and the period of the fetus. The period of the ovum includes approximately the first two weeks of prenatal life. During this time the fundaments of the fetal membranes are established and the differentiation of the embryo begins upon the germinal disk. The period of the embryo follows that of the ovum and terminates in the third lunar or fetal month. This is a phase of both rapid growth and differentiation, during which all of the chief systems and organs of the body are laid down, and the major features of the external body-form are established. The third or fetal period of prenatal life extends from the third lunar month to birth. The fetal period is an interval of rapid absolute increment rather than of striking differentiation, and the changes in external body-form take place quite slowly through slight differences in the relative growth rates of the various segments and parts of the body.

The changes in body-form and structure in the embryonic period are so rapid and striking that many of their characteristics may be presented by qualitative description and pictorial representation, such as are found in the classic atlases of His ('80–'85), Hochstetter ('07), and Rabl ('02), in the Normal Plates of Keibel and Elze ('08), and in numerous published accounts of individual specimens.

The changes in the fetal period, on the other hand, are relatively slow and continuous and can only be determined accurately by the use of the quantitative method. The application of the quantitative method to this material involves not only the collection of large series of numerical data but also their adequate analysis. Simple numerical tabulation and graphic representation of data may lead to many valuable general conclusions regarding them. But in this, as in all other phases of quantitative study of biologic phenomena, the full extent and significance of one's conclusions and the proper tests of their validity can be obtained only by statistical and analytic methods.

Although the application of simple quantitative methods to the investigation of prenatal human growth began many years ago, these studies form but a very small fraction of the contributions to this subject. Consequently our knowledge of growth and differentiation in the fetal period, which from its nature must be investigated with quantitative methods, remains very incomplete.

The present publication is a report on a part of a systematic quantitative study of the growth and structure of the body during the fetal period. It consists of an account of the changes in the dimensions and external proportions of the body as determined from a large number of original observations and from a colligation of all available published data of other investigators. These data have been treated analytically, studied for the effects of various important artifacts upon them, and are presented in condensed tabular, graphic, and analytic forms. As a whole, the investigation has been directed to the study of the trends of central tendency of the various dimensions, although certain observations regarding their variability are included.

Two phases of the work, the detailed consideration of individual differences and the application of some of the methods of the calculus to the material, are not considered in detail in this report. Studies in these fields are under way in this laboratory and will form the subjects of later publications.

II. Material and Methods

1. Amount, Source, and Racial Character of Material

The data upon which the present study is based consist of some 35,000 determinations of 71 external dimensions of the body. These measurements were made on a series of upwards of 400 selected human fetuses ranging from 2.3 to 54.4 cm in total or crown-heel length, which form a part of the collections of the Department of Anatomy and the Department of Obstetrics and Gynecology of the University of Minnesota.

The series of cases studied was selected from a much larger group by discarding all soft or distorted specimens. We think that practically all of our specimens would fall in classes "A" and "B" of Streeter's ('20) classification of fetal material and that by far the larger majority belong in class "A."

Our original measurements were made in 1919, 1920, and 1921. But a considerable amount of additional data was collected later in the course of a series of special studies on technical methods of treating the material, the nature of the artifactual errors affecting it, and similar subjects. In the present monograph the data obtained in these later studies have been added to the original collection. This procedure has required certain changes in the composition of the later tables and figures of this publication.

Our determinations may be divided into two major groups. The first and larger was made on fetuses preserved in 10 per cent formalin solution. The majority of specimens of 35 cm or more crown-heel length were also injected through the umbilical vein with a considerable amount of 10 per cent formalin alone or with the addition of 1 per cent chromic acid at the time of their preservation. All of the specimens of this series had been in the preservative for at least six months before they were measured and a number had been preserved for several years.

The second series consisted of 36 specimens that were used in an experimental study of the effects of injection and preservation on the external dimensions of the fetal body. These specimens were first measured when fresh and then at various intervals during their preservation. The last set of measurements made on this material, six months after preservation, was added to those of the first series.

A third set of measurements made on a series of 33 living, newborn children, to check the effect of birth moulding, is also described in a later part of this paper, but these data, being from living children, are not included in our final tabulations.

Only Caucasian material was used in this study. So few of the specimens were accompanied by clinical histories that it is impossible to give the racial stocks represented within this category. However, most of the material came from the Minneapolis General Hospital, the Elliott Memorial Hospital of the University of Minnesota, and similar local institutions. Table 1 is a summary of the racial elements found in a group of 1,013 unselected newborn children from one of these hospitals and probably gives a fair idea of the racial make-up of our material. It indicates a great diversity in racial stocks with a preponderance of northern European peoples.

Some idea of the general character of our material may also be obtained by comparing the physical development of the children born in the larger Minneapolis hospitals, which were the sources of the greater part of our cases, with that of newborn infants of other parts of the United States. A rough estimate of this kind can be made by

TABLE 1

Nationality of Parents of 1,013 Children Born in the Elliott Memorial Hospital, University of Minnesota, 1913–1920

Nationality	Number	Per cent of total number
American	238	23.49
Swedish	167	16.49
Norwegian	163	16.09
Jewish*	152	15.00
German	94	9.28
Finnish	41	4.05
Irish	36	3.55
French	27	2.67
English	22	2.17
Danish	14	1.38
Russian	14	1.38
Czech	11	1.09
Austrian	11	1.09
Scotch	5	0.49
Roumanian	5	0.49
All others†	13	1.28

* Mainly Russian. † Less than 5 of any single nationality.

the examination of the average birth-weights in Minneapolis and those of other larger American cities. Table 2A gives the published figures on the average weight of the Minneapolis newborn infants and table 2B gives similar figures for five other American cities.

TABLE 2

A. Weight of Newborn Children in Minneapolis

Observer	Number of cases	Average weight	
		Males (kg)	Females (kg)
Ramsey and Alley ('18)	300	3.39	3.28
Taylor ('19)	250	3.48*	3.38*
Scammon and Doyle ('20)	323	3.35†	3.25†
Adair and Scammon ('21)	100	3.38	3.37
Brinton ('22)	1931	3.38	3.32

B. WEIGHT OF NEWBORN CHILDREN IN OTHER LARGE AMERICAN CITIES

LOCATION	OBSERVER	NUMBER OF CASES	AVERAGE WEIGHT	
			Males (kg)	Females (kg)
Boston	Townsend ('96)	1000	3.43	3.32
New York	Holt ('99)	1000	3.40	3.26
New York	Montague and Hollingworth ('14)	2000	3.36	3.22
Philadelphia	Stockton-Hough ('85)	579	3.35	3.15
Baltimore	Meyer ('14)	2059	3.39‡	3.24‡
San Francisco	Faber ('20)	644	3.49	3.30

* Selected cases. † Mainly firstborn. ‡ Whites and negroes.

These figures indicate that there is comparatively little difference in the development of the newborn in the larger centers of population in this country, and that infants from this city approach very closely the average for the urban population of the country at large.

The character of the material and the diversity of the dimensions taken made it impossible to determine all dimensions for all speci-

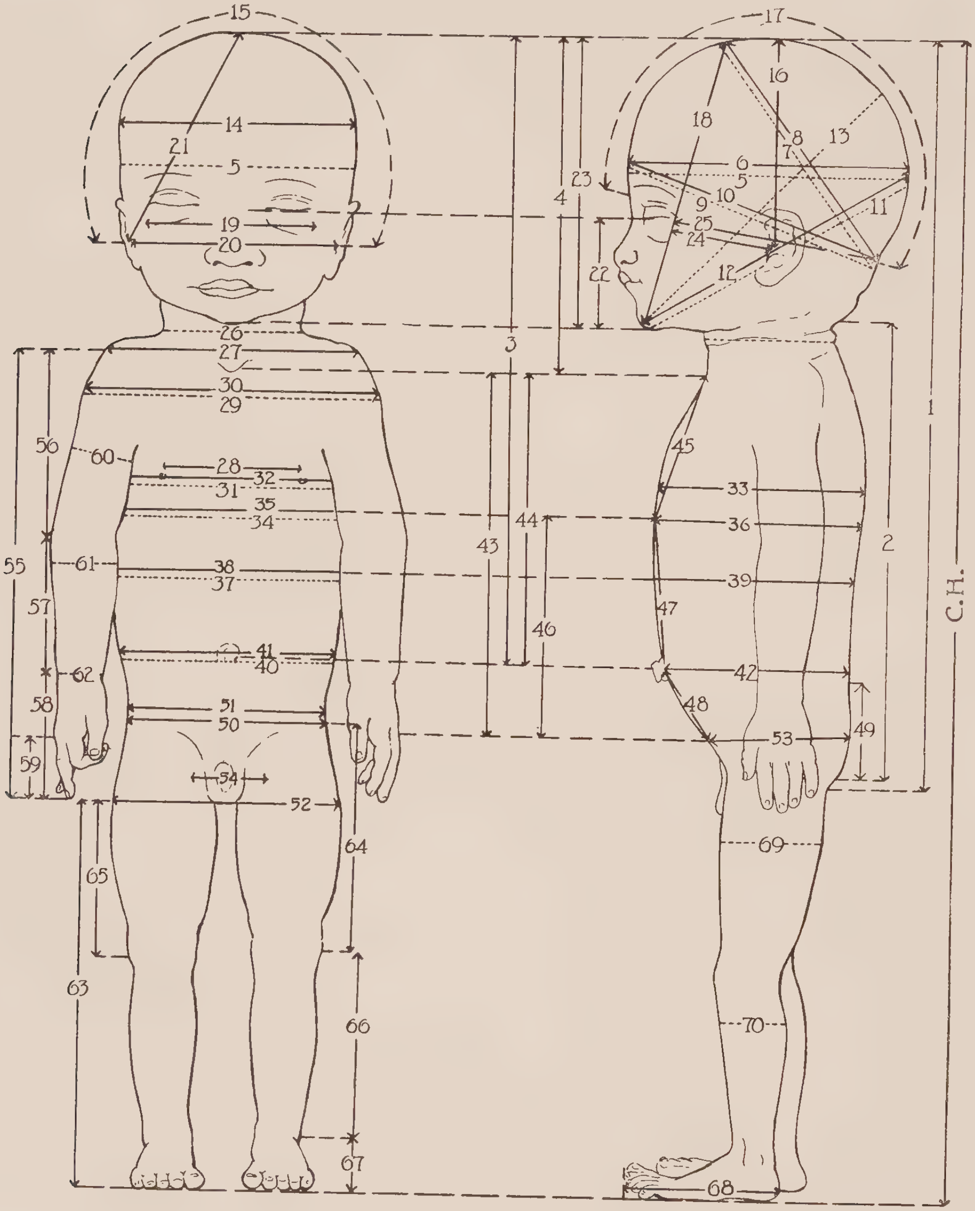
TABLE 3

DISTRIBUTION OF MEASUREMENTS MADE IN EACH 5 CM INTERVAL OF CROWN-HEEL BODY-LENGTH

CROWN-HEEL BODY-LENGTH (cm)	NUMBER OF CASES	
	Maximum	Minimum
0 to 5	18	0
5 to 10	30	1
10 to 15	45	27
15 to 20	28	17
20 to 25	52	22
25 to 30	46	20
30 to 35	36	24
35 to 40	36	17
40 to 45	29	17
45 to 50	24	17
50 to 55	27	15

FIGURE 1

The Anterior and Lateral Aspects of a Fetus of 25 cm Crown-Heel Length Showing the External Bodily Dimensions Measured in This Study



Linear dimensions and diameters indicated in solid line. Circumferences indicated in broken line.

1. Sitting-height (crown-rump length)
2. Spine length
3. Distance from crown to umbilicus
4. Distance from crown to sternal notch

5. Occipito-frontal (horizontal head) circumference
6. Occipito-frontal diameter
7. Suboccipito-bregmatic circumference
8. Suboccipito-bregmatic diameter
9. Suboccipito-frontal circumference
10. Suboccipito-frontal diameter
11. Occipito-mental circumference
12. Occipito-mental diameter
13. Large (menton-lambda) circumference
14. Bi-parietal diameter
15. Auriculo-vertex-auricular circumference
16. Vertical-auriculo-vertex distance
17. Suboccipito-vertex-nasion circumference
18. Menton-bregma diameter
19. Bi-malar distance or diameter
20. Bi-auricular diameter
21. Auriculo-vertex diameter
22. Nasion-menton distance
23. Vertical head height (crown-menton distance)
24. Orbito-auricular distance
25. Orbito-auriculo-suboccipital diameter
26. Circumference of neck
27. Bi-acromial diameter
28. Nipple to nipple (bi-mammary) distance
29. Bi-deltoid circumference
30. Bi-deltoid diameter
31. Circumference of thorax at nipples
32. Transverse diameter of thorax at nipples
33. Antero-posterior diameter of thorax at nipples
34. Circumference of thorax at xiphi-sternal junction
35. Transverse diameter of thorax at xiphi-sternal junction
36. Antero-posterior diameter of thorax at xiphi-sternal junction
37. Circumference of abdomen at tenth rib
38. Transverse diameter of abdomen at tenth rib
39. Antero-posterior diameter of abdomen at tenth rib
40. Circumference of abdomen at umbilicus
41. Transverse diameter of abdomen at umbilicus
42. Antero-posterior diameter of abdomen at umbilicus
43. Distance from sternal notch to pubis
44. Distance from sternal notch to umbilicus
45. Distance from sternal notch to xiphi-sternal junction
46. Distance from xiphi-sternal junction to pubis
47. Distance from xiphi-sternal junction to umbilicus
48. Distance from umbilicus to pubis
49. Height of pelvis (crest of ilium to rump)
50. Interspinous diameter of pelvis
51. Intercristal diameter of pelvis
52. Intertrochanteric diameter of pelvis
53. External conjugate diameter of pelvis
54. Bi-tuberous distance of pelvis
55. Length of upper extremity
56. Length of arm
57. Length of forearm
58. Length of hand
59. Length of middle finger
60. Circumference of arm
61. Circumference of forearm
62. Circumference of wrist
63. Length of lower extremity (trochanter to sole)
64. Length of thigh (posterior superior spine of ilium to knee)
65. Length of thigh (trochanter to knee)
66. Length of leg
67. Height of foot
68. Length of foot
69. Circumference of thigh
70. Circumference of calf

mens. This holds true particularly for measurements of very small segments of the body, which cannot be made with accuracy in the early part of the fetal period. Consequently both the number and the distribution of the determinations vary with the different dimensions. The maximum and minimum number of measurements made in each 5 cm interval of crown-heel body-length are given in table 3.

In the great majority of instances the number of specimens approaches more closely the maximum given above than it does the minimum. The total number of observations for a given measurement varies from 207 for the bi-tuberous diameter of the pelvis to 369 for the bi-parietal and the occipito-frontal diameters of the head. The average number of observations per dimension is approximately 300.

2. Methods of Collecting Data

A list of the 71 dimensions measured will be found in tables 163, 164, and 165, and figure 1 shows them in graphic form. A detailed statement of the methods employed in determining each dimension is included in the summary of findings. In general we have followed, for the standard anthropologic dimensions, the directions laid down by Hrdlička ('20) in his monograph on this subject. For the obstetric dimensions included in our list we have followed for the most part the accepted definitions given in standard texts on obstetrics.

Of the 71 dimensions studied, 22 were of the head and neck; 28 were of the trunk, including the pelvis; and 16 were of the extremities. The remaining 5 were measurements involving more than one major part of the body such as the crown-rump length and the total spine length. Eighteen were circumferences; the remainder were straight line dimensions, generally between two bony points.

All of the straight line measurements were made with standard anthropometric instruments. Sliding, vernier, steel calipers, reading to 1 mm on the major and 0.1 mm on the minor scale, were used for most of the dimensions, although a brass-bound meter-stick was employed for some of the larger ones. A right-angled plate was used in connection with the latter instrument to insure accurate readings. No material compression of the tissues was employed in taking these measurements.

The larger circumferences were determined with a steel tape marked in millimeters and readable to 0.5 millimeters. The smaller ones were determined with a fine, but inelastic, linen thread. The thread was wrapped snugly three times around the part at the desired level and the overlapping ends cut with a pair of sharp cataract scissors. The length of the thread was then measured with the tape and the value obtained divided by three to get the circumference. A considerable amount of the experimental error involved in the determination of small circumferences is eliminated by this technique. A very slight uniform pressure was used in taking all circumferences for the purpose of removing any slack in the measuring tape and at the same time avoiding any compression of the part.

All of the specimens were removed from the preserving fluid a few minutes before the actual measurements were taken in order to allow the superfluous moisture to evaporate from the external surface of the body, but no specimens were allowed to dry out before they were measured.

Most of the measurements were made by one observer (Calkins), although the majority of those of the extremities were made by Dr. Raymond Dittrich under our immediate supervision.

3. Selection of a Standard Dimension for the Comparison of Measurements

Practically all investigations of the growth of the human fetus rest upon determination of the changes in some form of measurement of the length of the body. Earlier investigators employed a number of dimensions as criteria of linear growth, but only two of these have been extensively used. These are the crown-heel length (total body-length, standing-height, vertex-heel length, mesencephalocalcanean line, Kopf-Fuss Länge, "stature"), and crown-rump length (sitting-height, vertex-breech length, stem-length, Kopf-Steiss Länge).

A number of arguments have been adduced in favor of the use of each of these dimensions as a standard. In general these may be placed under four headings, viz., applicability to the prenatal period, general use and previous acceptance, theoretical value, and reliability. Each of these will be considered separately.

One of the strongest arguments offered for the general use of the crown-rump standard in the prenatal life is that it may be applied to both fetuses and embryos and thus is of great value in following linear growth throughout the prenatal period. As is well known, the crown-heel length of the body cannot be determined, and, in fact, hardly exists in specimens under 2.5 cm, and for specimens below this dimension we depend on the crown-rump length.

This advantage is not as great as may appear at first sight, for it does not mean that crown-rump length can be used as a true expression of linear growth of all specimens below the point of establishment of a definite crown-heel length.

In the fetal period the body, when placed in the erect posture, has a fairly straight longitudinal axis passing through the vertex of the head and along the spinal column, and this axis may be projected to the level of the ischia or to the soles of the feet. In the former case this axis is approximated by the crown-rump length, and in the latter by the crown-heel length. In the embryo, however, the axis of the body is profoundly influenced by the growth and is thrown first into a series of parabolic curves, then into spirals (possibly of a logarithmic type), and finally is gradually extended to the fairly straight posture of the fetus.* Consequently, in these smaller specimens the crown-rump length does not measure a line approximating the body axis, but summates chords, at one time of a series of deep arcs, later of a series of spirals, and still later of a series of shallow arcs. Since we have practically no data on the relations that these chords bear to the curves and spirals that they subtend, we are quite unable to estimate the length of the body from them. In fact about all that may be safely stated regarding them is that they do not represent true measures of linear growth, and that they are constantly changing.

These criticisms of the determination of crown-rump length in the embryonic period do not mean that there is no value in this measurement. On the contrary, measurements of this kind may be of great value in estimating the stages of development of specimens. But it does mean that these data should not be used as criteria of linear growth, and in particular they should not be used in conjunction with curves representing linear growth in the later period of fetal life.

The wide acceptance in the past of the crown-heel length is no proof of its reliability, but it is a strong argument for its retention in order that the older data may be correlated with the new. We estimate that fully 90 per cent of the tens of thousands of printed observations of the various dimensions of the body, its weight and volume, and of the weights and dimensions of its various parts in the fetal period, are recorded with respect to the crown-heel length and without reference to the crown-rump length. These data are far too valuable to be discarded *en masse*, and many of them are quite irreplaceable. Furthermore, the great majority of the published records on postnatal growth of the human body are also referred to crown-heel length, and the correlation of these with data on fetal growth is largely dependent on the use of this measurement.†

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* Many of these changes in the longitudinal axis of the body are illustrated in Bujard's ('14) interesting monograph on the mechanism of the development of body-form in the early human embryo. Figure 44 of Bardeen's study on the development of the spinal column is particularly instructive as regards the changes in the *latter* part of the embryonic period.

† It is sometimes stated that Mall, who was much interested in the technique of body measurement in prenatal life, was of the opinion that the crown-rump measurement was the better one. Problems of this kind are to be answered by

An argument often advanced for the sole use of the crown-rump measure is the theoretical one that it is a real index of linear body growth, whereas the crown-heel length involves another type of growth through the inclusion of the lower extremities. This argument rests on the assumption that the growth of the stem of the body is of a single type, which, in fact, is far from true.

It should be recognized at the outset that, in determining the linear growth of the body, a complex measure is being used, regardless of the dimension that is employed as a standard. In the case of the crown-rump length this measure includes a vertical diameter of the head, the length in part of the spine, the length of a portion of the innominate bone, and the thickness of the soft tissues of the ischial tuberosities. The crown-heel length includes the height of the head, a part of the length of the spine, a portion of the innominate bone, and the length of the lower extremity. Each of these segments has its own particular rate of growth in the fetal period, and even the various parts of the same segment may have such individual rates. Thus, for example, we have found that each vertebra has its definite rate

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experiment rather than by appeal to authority. Nevertheless, the printed conclusions of this experienced investigator are of interest. They are as follows:

"The entire length of the body, the mesencephalocalcanean line, or the standing height of the embryo, is really the best single measurement of the embryo, for it is the one usually made by obstetricians as well as by anthropologists. It has been said that the standing height of embryos and fetuses is an unsatisfactory measurement on account of its uncertainty, but my experience obtained from the measurement of many embryos, Fig. 146, shows that it is no more variable, probably less so, than either the sitting height or that of the spinal column. . . . ." (Manual of Human Embryology, F. Keibel and F. P. Mall, eds., 1910, I,191.)

"It seems to me that for the present we must continue to employ the sitting height or the crown-rump measurement as the standard. Next in importance is the standing height, and, judging by the form of a curve made by abscissas and ordinates to determine the means by the graphic method, I do not find that one is more variable than the other (Figs. 145 and 146). The sitting height is the measurement most easily, and, therefore, the one usually made upon young specimens, and the standing height upon older ones. These two measurements can be compared directly with the two standard measurements made after birth. . . . . That the standing height is just as good a measurement as the sitting height is further found by the experience of Pfitzner, who was at first opposed to it, but after having made many more measurements he selected it as the best standard measurement with which to compare all others. This last statement is based upon the careful measurements of 5000 cadavers." (Manual of Human Embryology, F. Keibel and F. P. Mall, eds., 1910, I, 194.)

of growth in the fetal period and that these rates diminish from head to pelvis. Consequently, the question as to which one of these dimensions is the "truer" measure of linear growth has no significance. Theoretically, any dimension of the body could be used equally well as a standard from this point of view. The important criteria are the technical errors of its determination.

The question of selection of a "standard" measurement has seemed sufficiently important to warrant a special study of certain phases of it in connection with the present investigation. Our method of approach has been to make seriatim measurements, under controlled conditions, of the crown-heel and crown-rump lengths of the same specimen, to plot these observations, and to compute a number of expressions of the variability of the individual measurements from the means. These experiments were carried out on living, newborn infants, on fresh specimens, on specimens preserved in formalin, on specimens preserved in formalin and set in plaster bases to prevent errors due to postural changes, and on plaster of Paris casts (hardened by the oil-method) of fetuses.

The measurements of the larger specimens were made with a Schultz ('20) measuring apparatus, those of the smaller specimens were made with standard, vernier, anthropometric calipers.

Three observers took part in each experiment. One held the specimen in place, the second measured alternately the crown-heel and the crown-rump lengths of the specimen and the third recorded the measurements. The scale of the measuring instrument was so placed that the observer who determined the measurement could not see the reading. The observer who read the scale and recorded each measurement was so placed that he could not be seen by the person taking the measurement. The whole series of experiments was completed before any computations were made. All of these precautions were taken to avoid the subjective element in the findings.

Each experiment required from one-half to three hours. Rest periods were taken at fifteen-minute intervals and these were recorded with the readings.*

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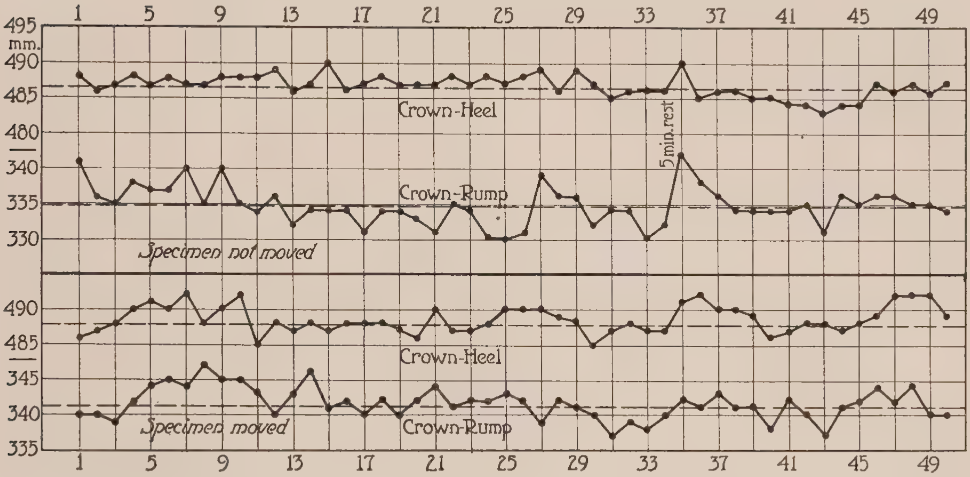
* It was found that fatigue had little or no effect on the accuracy of these measurements, and the determinations made just before a rest period approached the mean quite as closely as those taken shortly after rest. But distractions of attention, through outside disturbances and the like, had a marked effect on the precision of mensuration.

The results obtained are illustrated in part by figures 2 and 3. The figures are typical graphic representations of the findings. The individual observations are shown, in series as taken, by dots con-

FIGURE 2

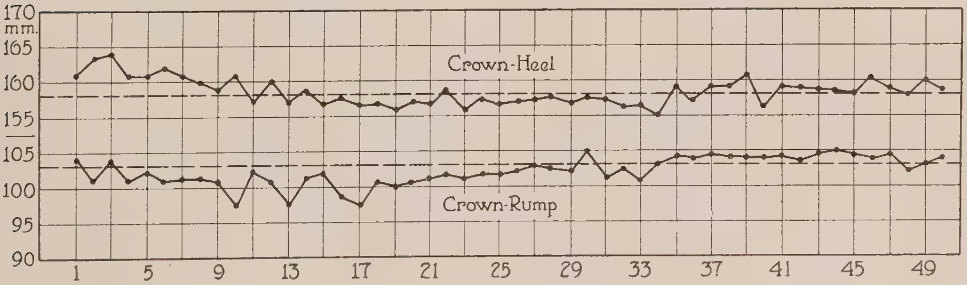
ONE HUNDRED SERIATIM DETERMINATIONS OF THE CROWN-HEEL AND CROWN-RUMP MEASUREMENTS OF A FRESH SPECIMEN APPROXIMATELY 488 MM IN CROWN-HEEL LENGTH



The dots, connected by solid lines, represent the individual observations. The broken line is the average of all observations in the series. The first 50 observations (shown in the upper panel) were made without moving the specimen. In the second series of 50 observations (lower panel) the specimen was moved between each measurement. The lengths were determined with a Schultz measuring instrument. The technique of measurement is described in the text.

FIGURE 3

FIFTY SERIATIM CROWN-HEEL AND CROWN-RUMP MEASUREMENTS OF A PRESERVED FETUS APPROXIMATELY 158 MM IN CROWN-HEEL LENGTH



The graphic treatment of the data was the same as that described in connection with figure 2. The lengths were determined with steel anthropometric vernier calipers.

nected by solid lines, and the mean for the entire series of readings is drawn in broken line.

Table 4 includes the essential data of a number of the experiments and the computations made from them. The variabilities of the two measurements are shown by their absolute and percentage ranges, their "range indices" (range of variation in crown-rump length expressed as a percentage of range of variation in crown-heel length), their standard deviations, their coefficients of variation, and their "coefficient of variation indices" (coefficient of variation of crown-rump length expressed as a percentage of the coefficient of variation of crown-heel length).

TABLE 4

Results of Tests of the Reliability of Crown-heel and Crown-rump Measurements

Material		Number of seriatim measurements	Measurements			Range of measurements			Standard deviation (mm.)	Coefficient of variation (per cent.)	Index of coefficient of variation (per cent.)
			Mean (mm.)	Maximum (mm.)	Minimum (mm.)	Absolute (mm.)	Per cent. of mean	Range index (per cent.)			
A Living newborn infant	C R	42	342.83	352	334	18	5.25	131.9	4.55	1.33	135.6
	C H		527.09	537	516	21	3.98		4.79	0.91	
B Fresh specimen No. 1	C R	80	259.06	265	252	13	5.02	173.7	2.41	0.93	160.4
	C H		381.11	387	376	11	2.89		2.22	0.58	
C Fresh specimen No. 2	C R	346	289.98	295	283	12	4.14	161.7	1.92	0.66	150.0
	C H		423.59	429	418	11	2.56		1.87	0.44	
D Fresh specimen No. 3 (not moved)	C R	50	334.78	342	330	12	3.58	248.6	2.77	0.83	267.7
	C H		486.74	490	483	7	1.44		1.52	0.31	
E Fresh specimen No. 3 (moved)	C R	50	341.38	347	337	10	2.93	204.9	2.19	0.64	152.4
	C H		488.58	492	485	7	1.43		1.79	0.42	
F Preserved specimen	C R	50	103.14	105	97.5	7.5	7.27	143.7	1.22	1.83	212.8
	C H		158.03	164	156.	8	5.06		1.35	0.86	
G Preserved specimen (set in plaster)	C R	100	159.66	161	157	4	2.50	190.8	0.75	0.47	162.1
	C H		228.89	230	227	3	1.31		0.66	0.29	
H Plaster cast of "G"	C R	50	157.02	160	156	4	2.55	289.8	0.58	0.37	142.3
	C H		226.26	227	225	2	0.88		0.59	0.26	

In general these figures show the following results. The *absolute range of variation* in the determination of crown-rump length is greater than that of crown-heel length in six of the eight series, the two exceptions being the living, newborn infant and one preserved specimen. The *relative range of variation* was always greater in the determination of crown-rump than in the determination of crown-heel length by 30 to 90 per cent. The standard deviation of the determination of crown-rump length was greater than that of the crown-heel length in five instances and less in two. In one instance (the plaster of Paris cast) the standard deviations of the two measures were approximately equal. The *coefficient of variation* of crown-rump length was always greater than that of crown-heel length, exceeding it by 35 to over 165 per cent in the various series.

These results lead us to the conclusion that the determination of crown-heel length, in so far as it may be tested by this type of experiment, has a higher absolute reliability in the great majority of instances, and a higher relative reliability in all instances, than does the determination of crown-rump length. Therefore we have used the crown-heel length or total length as our standard measurement throughout this study, although we have always included the mean crown-rump length, for purposes of comparison, in our tables.

4. Determination and Elimination of Artifacts in Data

Quantitative data, as ordinarily obtained, on the external dimensions of the body in the fetal period are affected by a number of errors. These errors may be divided into two general groups. The first group includes the errors of technique that occur in any extended series of mensurations—slight inaccuracies in the manipulation and reading of instruments, small clerical mistakes in recording observations, and the like. In a large series of observations, these errors may be expected to follow the laws of chance and to be compensatory in their effect upon average values. The second group of errors, due to artifacts, however, which are introduced from a number of sources, are not compensatory but cumulative. They cannot be eliminated by the mere accumulation of a large number of observations but they can be greatly reduced by weighting the observed results with values determined by the quantitative study of the factors involved. Our investigation indicates that, in this type of study, errors of the latter group come mainly from four sources, viz., (a) changes in the body-form of the specimens before preservation, (b) artifacts produced by simple preservation in formalin, (c) artifacts produced by injection and subsequent preservation in formalin, (d) changes in the dimensions of the cephalic region through the moulding of the head during birth, and (e) modifications of the form of the thorax that accompany the partial or complete establishment of respiration. These will now be considered separately in detail.*

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* Todd's ('25, '28) studies of the variability and errors of whites and negroes may be cited as the outstanding example of this type of work for the adult.

a. Changes in the body-form of specimens before preservation.—The errors introduced by the flaccidity of the specimens before preservation are most marked in the smaller fetuses and affect particularly the circumferences of the soft parts. They are not necessarily cumulative, since slight deformations in one plane may be balanced by similar distortions in the opposite one. Most of these errors are avoided by the elimination of all specimens not in the best condition. There seems to be no doubt, however, that certain dimensions of the abdomen, in particular the transverse diameter at the level of the umbilicus, are generally increased in our specimens by the effect of gravity when the specimens are placed in the horizontal position prior to injection or fixation. This artifact will be considered in more detail in connection with the later discussion of the individual measurements.

b. Artifacts produced by simple preservation in formalin.—It is well known that when fresh tissues are placed in aqueous solutions of formaldehyde they undergo considerable changes in mass. The earlier quantitative work on this subject was carried out mainly in connection with studies of the central nervous system. Thus Hrdlička ('06) found that the brains of various mammals and birds, when placed in 10 per cent liquor formaldehydi, increased from 13 to 24 per cent in weight, but after eighteen months' preservation in this fluid they had undergone a secondary reduction in mass to about 8 per cent below their original fresh weight. A like study by King ('10) on the effect of formalin fixation on the rat's brain gave somewhat similar results. The effect of 10 per cent formalin on the dimensions of fetuses has been studied by Patten and Philpott ('21) and by Schultz ('19). The former found an average increase of 4.8 per cent in the crown-rump lengths of 22 pig embryos after six months' preservation in 10 per cent commercial formalin. Schultz determined the sitting-heights, the head breadths, and the head lengths of 18 human fetuses, first fresh and later after preservation in formalin for various periods up to nine months. Thirty-six weeks after preservation the sitting-height had decreased, on an average, 2.54 per cent, while the head length had increased 0.88 per cent and the head breadth had increased 4.83 per cent. The greatest and most rapid changes in these dimensions took place in the beginning of the period of preservation.

We have supplemented these observations by an experimental study of the changes produced by formalin fixation and preservation on 10 dimensions of the head and on the crown-heel and the crown-rump lengths. Ten specimens were used in this study. They were measured when fresh and then at monthly intervals for six months after preservation. The results of this experiment are presented in table 5 and are shown in the form of curves in figure 4.

TABLE 5

Effects of Formalin Preservation on the Various External Dimensions of the Body

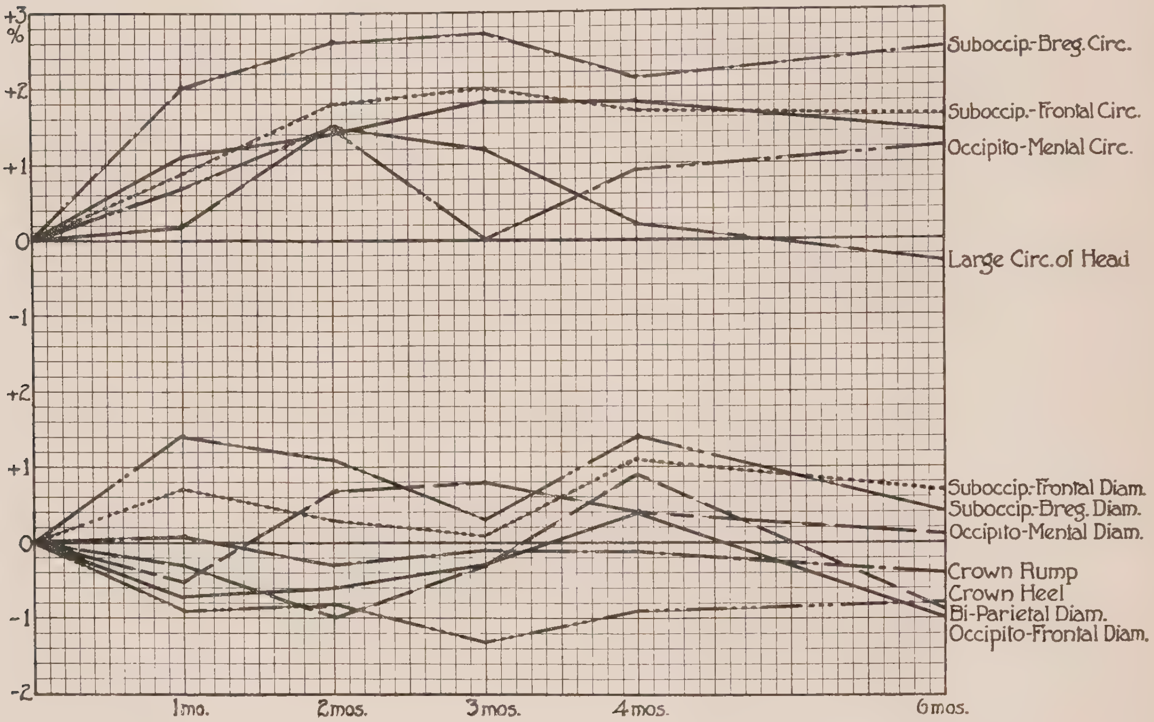
Dimension	Percentage change after preservation in 10 per cent. formalin for:				
	1 month	2 months	3 months	4 months	6 months
Crown-heel length	-0.9	-0.8	-1.3	-0.9	-0.8
Crown-rump length	+0.1	-0.3	-0.1	-0.1	-0.4
Horizontal head circumference	+1.1	+1.4	+1.8	+1.8	+1.4
Suboccipito-bregmatic circumference	+2.0	+2.6	+2.7	+2.1	+2.5
Suboccipito-frontal circumference	+0.9	+1.8	+2.0	+1.7	+1.6
Occipito-mental circumference	+0.7	+1.5	±0.0	+0.9	+1.2
Largest head circumference	+0.2	+1.5	+1.2	+0.2	-0.3
Bi-parietal diameter	-0.3	-1.0	-0.3	+0.9	-0.9
Occipito-frontal diameter	-0.7	-0.6	-0.3	-0.4	-1.0
Occipito-mental diameter	-0.5	+0.7	+0.8	+0.4	+0.1
Suboccipito-frontal diameter	+0.7	+0.3	+0.1	+1.1	+0.6
Suboccipito-bregmatic diameter	+1.4	+1.1	+0.3	+1.2	+0.4

These data indicate that the changes following preservation in 10 per cent formalin are relatively slight. Of the 12 dimensions, 7 departed less than 1 per cent from the original figure before preservation, 4 showed a departure of 1 through 1.6 per cent, and only 1 showed a deviation of over 2 per cent. We found a very small decrease in the crown-rump length or sitting-height, and the departure of the bi-parietal diameter from the dimension as observed in the fresh material was a negative value, in contrast to the positive value as found by Schultz. Our specimens showed an average decrease of 1 per cent while Schultz found an average increase of 0.88 per cent.

Since these two series of measurements were made in much the same way, and probably with equal care, it appears that the effect of formalin preservation is somewhat variable, although it is quite possible that part of these deviations represent experimental error in taking the measurements rather than changes in the parts measured.

FIGURE 4

The Effect of Simple Preservation in Formalin on External Dimensions of the Body



Abscissa: Time of preservation in months. Ordinates: Percentage changes from values as determined for fresh material. The curves are based on the data presented in table 5.

c. *Artifacts produced by injection and subsequent preservation in formalin.*—It is common laboratory practice to inject the bodies of larger fetuses and newborn children with 10 per cent formalin solution, generally through the umbilical vein. This technique has great advantages, for it fixes the tissues intravascularly in a much more complete manner than does immersion in formalin alone, but, on the other hand, it produces marked changes in certain of the external dimensions of the body. Since the majority of our specimens of 35 cm and over, in total or crown-heel body-length, were injected, a series of experiments similar to those described in connection with the effect of simple preservation was carried out to determine the amount and duration of the error produced by this technique.

Twenty-six specimens, ranging from 36.8 to 54.2 cm in total body-length were used in this experiment. Fifty-nine dimensions were measured on each specimen while fresh. Each specimen was then injected with approximately 30 per cent of its body-weight of 10 per cent formalin solution through the umbilical vein, and the same set of measurements was repeated immediately after the injection was completed and the cord tied. The specimens were then placed in 10 per cent formalin and were subsequently measured at one, two, three, four, and six months after the original injection. The percentage change in each dimension for each period was then computed separately for the individual specimens and the results averaged. These figures are shown in table 6 and are represented graphically in figures 5a to 5d, inclusive.

Taken as a whole, the external dimensions of the body are increased by injection. The only exceptions to this rule are the length of the upper extremity, the distance from the vertex to the sternal notch, the distance from sternal notch to xiphi-sternal junction, and the height of the pelvis, which remain stationary or are slightly reduced. The amount of increase varies from a fraction of 1 per cent, in the case of certain dimensions of the head and extremities, to 20.3 per cent, in the case of the antero-posterior diameter of the abdomen, and 22.2 per cent in the case of the external conjugate diameter of the pelvis. As a rule, measurements of soft parts are increased more than those between bony points, and circumferences are increased more than lengths or diameters. In summary, we find that 7 were increased less than 1 per cent; 4, between 1 and 2 per cent; 5, from 2 and through 3 per cent; 13, between 3 and 5 per cent; 17, between 5 and 10 per cent; 9, between 10 and 15 per cent; and 4, over 15 per cent. The crown-heel length was increased 1.5 per cent and the crown-rump length, 1.6 per cent.

Preservation in formalin subsequent to injection also affects the various dimensions in quite different ways. The most common change, illustrated, for example, by many of the diameters of the head and certain of the circumferences of the trunk and extremities, is a

TABLE 6

Effects of Formalin Injection and Preservation on the Various External Dimensions of the Body

Dimension	Percentage change after injection	Percentage change after injection and preservation for:					Percentage correction for injection and preservation for 6 months
		1 month	2 months	3 months	4 months	6 months	
General							
Standing height (crown-heel length)	+ 1.5	+ 0.9	+ 1.0	+ 0.8	+ 0.7	+ 0.9	– 0.8
Sitting height (crown-rump length)	+ 1.6	+ 1.0	+ 0.9	+ 0.7	+ 0.4	+ 0.5	– 0.4
Spine length	+ 4.2	+ 5.6	+ 5.4	+ 5.4	+ 5.6	+ 4.3	– 4.0
Crown to umbilicus	+ 2.5	+ 2.8	+ 2.8	+ 3.0	+ 3.0	+ 3.1	– 2.9
Crown to suprasternal notch	– 4.1	– 4.8	– 4.6	– 4.6	– 4.5	– 4.3	+ 4.7
Head and Neck							
Occipito-frontal circumference	+ 3.8	+ 4.5	+ 4.7	+ 4.6	+ 4.6	+ 4.5	– 4.3
Occipito-frontal diameter	+ 2.6	+ 3.4	+ 3.4	+ 3.2	+ 2.8	+ 2.6	– 2.5
Suboccipito-bregmatic circumference	+ 4.6	+ 5.6	+ 5.5	+ 5.6	+ 5.4	+ 4.8	– 4.5
Suboccipito-bregmatic diameter	+ 3.8	+ 5.6	+ 5.0	+ 5.2	+ 5.3	+ 3.9	– 3.6
Suboccipito-frontal circumference	+ 5.1	+ 6.9	+ 6.6	+ 6.7	+ 6.4	+ 6.1	– 5.6
Suboccipito-frontal diameter	+ 4.3	+ 6.0	+ 6.0	+ 5.5	+ 5.7	+ 4.9	– 4.6
Occipito-mental circumference	+ 7.7	+ 8.7	+ 9.8	+ 9.1	+ 7.3	+ 7.4	– 6.6
Occipito-mental diameter	+ 4.8	+ 6.0	+ 5.6	+ 5.2	+ 4.5	+ 2.9	– 2.7
Large circumference (menton-lambda)	+ 5.4	+ 7.0	+ 6.4	+ 6.2	+ 5.3	+ 5.0	– 4.7
Bi-parietal diameter	+ 4.4	+ 4.7	+ 4.4	+ 4.2	+ 4.1	+ 3.9	– 3.6
Auriculo-vertex-auricular circumference	+ 2.9	+ 2.5	+ 3.1	+ 2.0	+ 2.5	+ 3.3	– 3.1
Vertical auriculo-vertex distance	+ 3.1	+ 1.3	+ 2.0	+ 1.7	+ 0.7	+ 0.6	– 0.4
Suboccipito-vertex-nasion circumference	+ 0.9	+ 0.6	+ 0.9	+ 0.2	– 0.2	+ 0.1	± 0.0
Menton-bregma diameter	+ 4.6	+ 4.6	+ 5.4	+ 5.2	+ 5.1	+ 4.6	– 4.3
Bi-malar distance (or diameter)	+ 5.7	+ 5.9	+ 6.2	+ 5.5	+ 5.0	+ 1.3	– 1.0
Bi-auricular diameter	+ 9.5	+12.5	+11.4	+11.2	+10.1	+ 8.0	– 7.2
Auriculo-vertex diameter	+ 1.6	+ 1.5	+ 1.7	+ 2.1	+ 1.7	+ 0.7	– 0.5
Nasion-menton distance	+ 6.6	+ 6.8	+ 7.7	+ 8.1	+ 7.0	+ 6.0	– 5.4
Crown-menton distance (V.H.H.)	+ 4.6	+ 5.1	+ 5.7	+ 6.0	+ 4.7	+ 4.3	– 4.0
Orbito-auricular distance	+ 6.5	+ 8.1	+ 6.0	+ 6.2	+ 4.7	+ 2.0	– 1.7
Orbito-auriculo-suboccipital diameter	+ 8.3	+11.5	+10.8	+ 9.5	+ 9.6	+ 7.7	– 6.9
Circumference of neck	+18.4	+23.3	+24.0	+24.1	+22.5	+22.0	–17.5
Trunk							
Bi-acromial diameter	+ 5.4	+ 4.2	+ 3.3	+ 2.5	+ 3.3	+ 0.8	– 0.5
Nipple to nipple distance	+ 5.1	+ 2.2	+ 2.1	+ 2.0	+ 1.9	+ 1.2	– 1.0

TABLE 6. *Concluded*

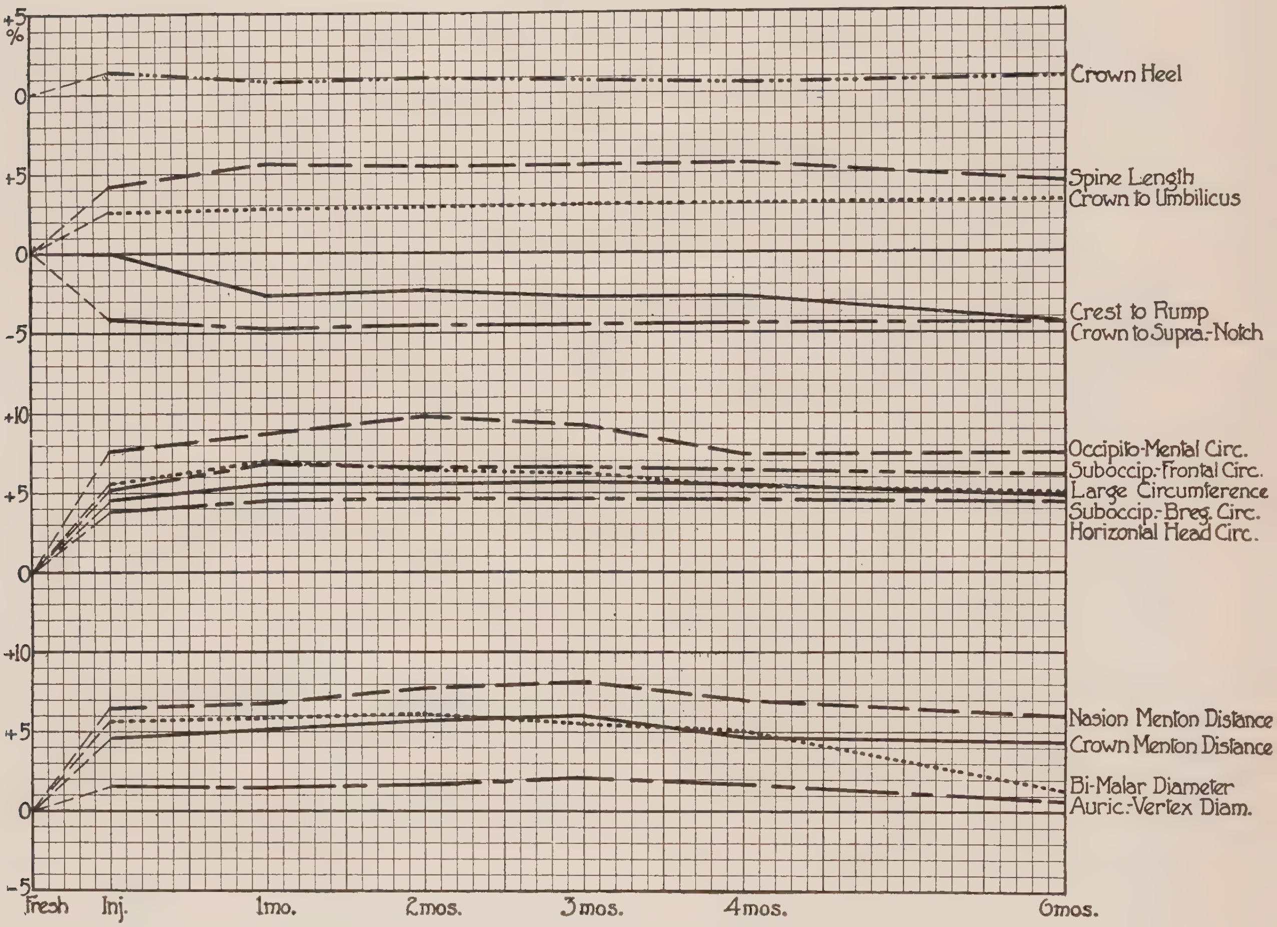
Effects of Formalin Injection and Preservation on the Various External Dimensions of the Body

Dimension	Percentage change after injection	Percentage change after injection and preservation for:					Percentage correction for injection and preservation for 6 months
		1 month	2 months	3 months	4 months	6 months	
Trunk—*concluded*							
Bi-deltoid circumference	+ 9.7	+11.7	+12.6	+12.3	+10.7	+10.5	− 8.9
Bi-deltoid diameter	+ 5.7	+ 7.0	+ 6.5	+ 5.9	+ 5.0	+ 4.1	− 3.8
Circumference at nipples	+13.5	+15.7	+16.3	+15.7	+15.3	+14.9	−12.9
Transverse diameter at nipples	+ 8.0	+10.9	+10.0	+10.9	+10.4	+10.4	− 9.2
Antero-posterior diameter at nipples	+14.3	+15.1	+15.6	+15.7	+15.7	+15.2	−13.0
Circumference at xiphi-sternal junction	+11.9	+12.7	+13.0	+13.1	+12.6	+12.2	−10.8
Antero-posterior diam. at xiphi-sternal junc.	+13.8	+13.8	+13.5	+13.6	+13.3	+12.8	−11.1
Transverse diameter at xiphi-sternal junc.	+ 4.6	+ 4.7	+ 4.4	+ 4.6	+ 4.3	+ 4.0	− 3.7
Circumference at tenth rib	+14.4	+14.3	+14.2	+14.6	+14.3	+13.9	−12.2
Antero-posterior diameter at tenth rib	+14.7	+13.7	+13.4	+13.5	+13.4	+13.0	−11.2
Transverse diameter at tenth rib	+ 2.8	+ 1.4	+ 1.7	+ 1.5	+ 1.4	+ 1.4	− 1.2
Circumference at umbilicus	+19.5	+19.8	+20.0	+20.0	+20.2	+19.7	−16.2
Transverse diameter at umbilicus	+ 3.3	+ 1.9	+ 2.5	+ 2.4	+ 2.6	+ 3.0	− 2.7
Antero-posterior diameter at umbilicus	+20.3	+21.4	+20.4	+20.3	+20.8	+19.7	−15.9
Sternal notch to pubis	+ 8.4	+ 7.8	+ 7.9	+ 7.8	+ 7.8	+ 7.6	− 6.9
Sternal notch to umbilicus	+ 9.4	+10.3	+10.4	+10.3	+10.3	+ 9.8	− 8.7
Sternal notch to xiphi-sternal junction	± 0.0	+ 4.2	+ 4.3	+ 4.6	+ 5.1	+ 4.1	− 3.6
Xiphi-sternal junction to pubis	+11.2	+ 7.5	+ 7.1	+ 6.5	+ 6.9	+ 6.6	− 5.7
Xiphi-sternal junction to umbilicus	+13.8	+12.0	+11.8	+11.8	+11.0	+11.0	− 9.3
Umbilicus to pubis	+14.7	+ 8.9	+ 8.1	+ 7.6	+ 8.5	+ 7.0	− 4.9
Pelvis							
Height of pelvis (crest of ilium to rump)	− 0.2	− 2.7	− 2.4	− 2.8	− 2.8	− 4.6	+ 5.0
Interspinous diameter	+ 0.4	+ 2.3	+ 3.8	+ 2.6	+ 3.6	+ 3.0	− 1.8
Intercristal diameter	+ 3.0	+ 5.7	+ 7.0	+ 7.2	+ 6.9	+ 5.9	− 5.3
Intertrochanteric diameter	+ 1.3	+ 3.1	+ 3.8	+ 4.2	+ 3.5	+ 3.0	− 2.8
External conjugate diameter	+22.2	+28.2	+29.5	+27.1	+26.5	+22.4	−17.5
Bi-tuberous distance	+ 7.6	+ 6.9	+ 7.3	+ 5.4	− 2.0	− 2.3	+ 5.6
Extremities							
Length of upper extremity	± 0.0	− 0.5	− 0.2	− 0.1	− 0.2	− 0.3	+ 0.4
Length of lower extremity	+ 0.8	+ 0.3	+ 0.6	+ 0.3	+ 1.1	+ 0.9	− 0.9
Circumference of arm	+ 7.2	+10.8	+10.1	+10.5	+10.2	+ 9.8	− 8.2
Circumference of thigh	+ 3.8	+ 7.5	+ 8.0	+ 8.6	+ 8.8	+ 7.5	− 6.8

slow and slight increase for one to three months after injection, followed by a rather slow decrease for the remainder of the period. Another group of measurements, illustrated by the length of the lower extremity, shows a small but steady decline. Still others, such as the transverse diameter of the thorax at the xiphi-sternal junction, show practically no change in formalin after injection.

FIGURE 5a

The Effect of Injection and Subsequent Preservation in Formalin on the Major Dimensions of the Body and Certain Head Measurements

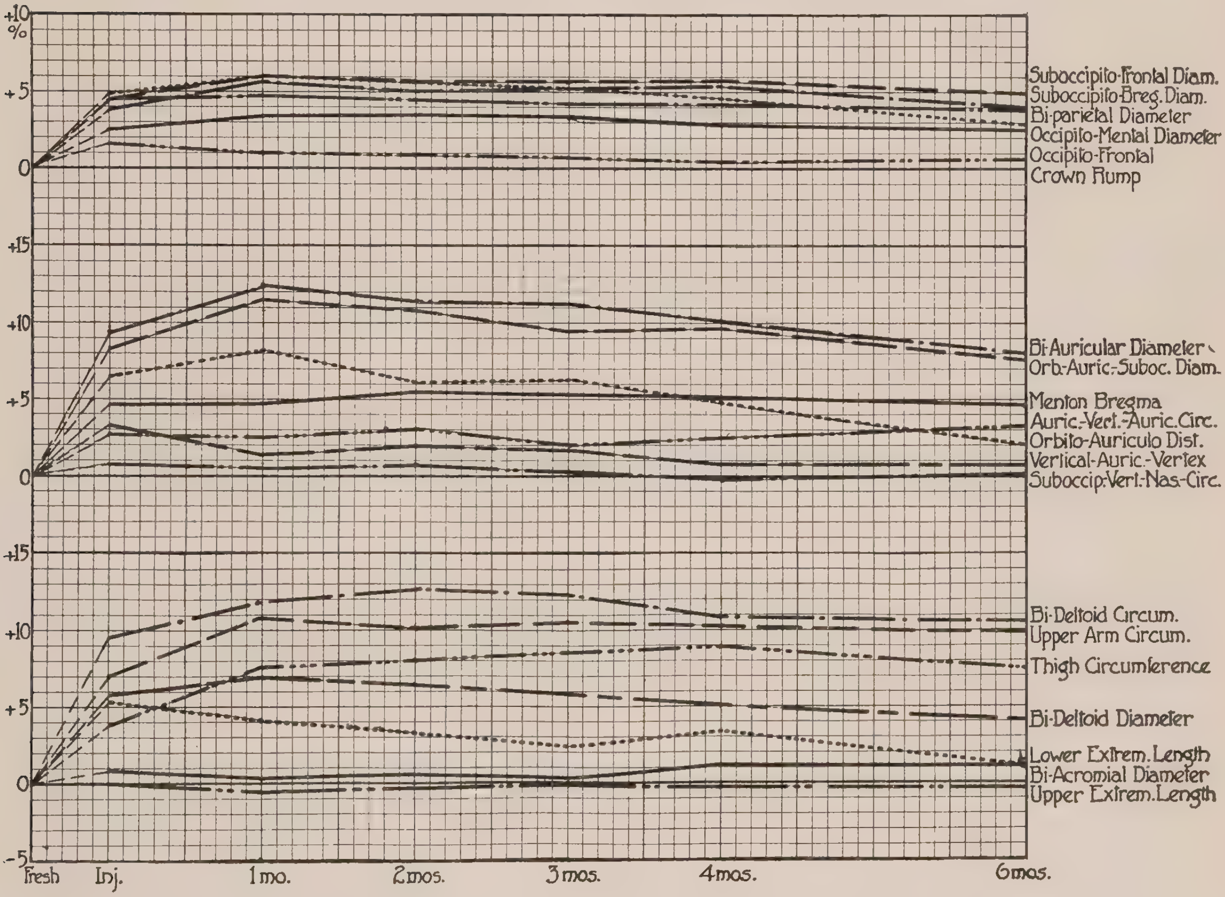


Abscissa: Time of preservation in months. Ordinates: Percentage changes from values as determined for fresh material. The curves are based on the data presented in table 6.

While many dimensions undergo distinct changes during the first few months of preservation after injection, they seem to change relatively little after this time. The graphs presented in figures 5a to 5d, inclusive, show that 55 of the 58 dimensions tested remained practically stationary after four months in 10 per cent formalin. The remaining 3 still continued to decline very slowly. Most of these are dimensions that were greatly increased by injection. Thirty-five of the 58 measurements show a change of 0.5 per cent or less between four and six months, 10 a change from 0.5 and through 1.0 per cent, 8 show a change of between 1.0 and 2 per cent, and 5 a change of over 2 per cent. The last group includes the measurements of highly vari-

FIGURE 5b

THE EFFECT OF INJECTION AND SUBSEQUENT PRESERVATION IN FORMALIN ON CERTAIN DIMENSIONS OF THE HEAD AND THE EXTREMITIES

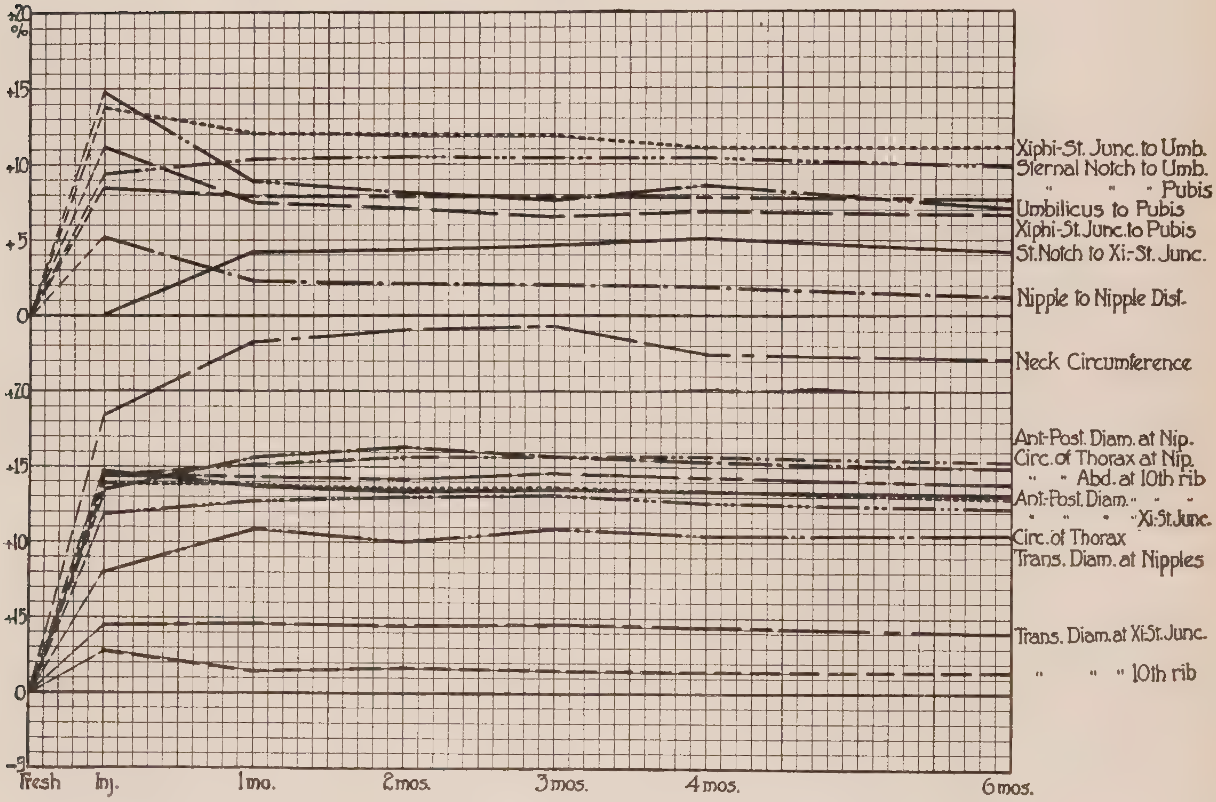


Abscissa: Time of preservation in months. Ordinates: Percentage changes from values as determined for fresh material. The curves are based on the data presented in table 6.

able dimensions in which there is a large technical error of determination. The average change in all dimensions in the period between four and six months is about 0.8 per cent, which is not a large absolute value for most dimensions of the body in the last three months of gestation.

FIGURE 5c

The Effect of Injection and Subsequent Preservation in Formalin on Certain Dimensions of the Trunk

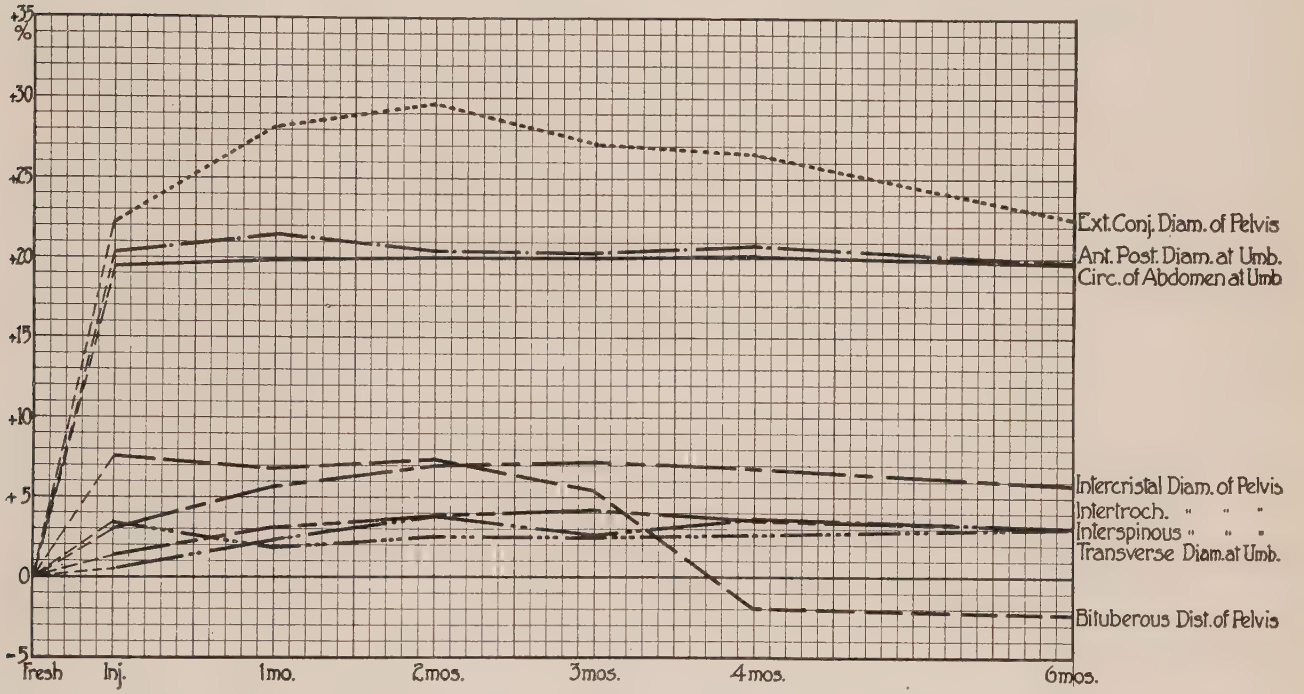


Abscissa: Time of preservation in months. Ordinates: Percentage changes from values as determined for fresh material. The curves are based on the data presented in table 6.

After injection and six months' preservation in formalin the average percentage change of all measurements from their values in fresh specimens is approximately 5.8 per cent. Seven dimensions were changed between 0 and 1 per cent; 10, between 1 and 3 per cent; 15, between 3 and 5 per cent; 16, between 5 and 10 per cent; 6, between 10 and 15 per cent; and 4, between 15 and 20 per cent. The effects of injection and preservation on the various types of measurement were much the same as those of injection alone, for generally the dimensions between bony points are less affected than measurements of soft parts, and diameters or lengths are less affected than circumferences. Four dimensions showed a decrease in average size at the close of the experiment and the remaining 54 were increased.

FIGURE 5d

The Effect of Injection and Subsequent Preservation in Formalin on Certain Dimensions of the Trunk and Pelvis



Abscissa: Time of preservation in months. Ordinates: Percentage changes from values as determined for fresh material. The curves are based on data presented in table 6.

The application of these findings to our observed data is discussed in the section on analysis of data, and the changes in the individual dimensions are considered in more detail in connection with the various sections of the summary of findings.

d. Changes in the cephalic region due to birth moulding.—That the birth process may produce a considerable change in the shape of the fetal head has long been accepted by obstetricians, but the exact nature of this moulding has not been investigated in detail, although studies that consider the subject from a qualitative viewpoint have appeared from time to time in the literature. The only work dealing with the actual amount of change in any given head dimension seems to be that of Stumpf ('07). This author's study was confined mainly to the determination of the amount of change in the circumferences of the head in the suboccipito-bregmatic and suboccipito-frontal planes. It was based upon some 200 newborn children measured soon after birth and again on the seventh day. He found an actual decrease in these dimensions amounting, on the average, to 8.6 mm and 6.0 mm, respectively. These figures were all obtained from living children, none of whom were born by forceps extraction or through contracted pelves, and hence are representative of average normal cases, rather than abnormal ones such as stillborn children may well be. They are, therefore, of little aid in correcting for the moulding changes that were obviously present in our material.

In order to arrive as nearly as possible at the exact size and proportions of the fetal head *in utero and at term*, it was therefore necessary to make a special series of head measurements of newborn children in which head moulding was eliminated. Two types of cases were selected for the purpose: first, infants born by Caesarean section, without the previous occurrence of any labor pains, and second, infants born by breech extraction where this extraction was easily and quickly performed. Considerable care in the selection of the latter group was necessary as one will often observe moderate moulding in some breech-born infants. Second twins were found most satisfactory, for the birth canal is usually well dilated by the passage of the first twin.

In all, 33 infants were studied, the measurements being made in the first day of postnatal life in order that growth changes might not alter the dimensions. Of these children, 5 were premature, according to the menstrual history and the body-length, and one was postmature. These 6 cases were not included in the determinations of the averages for the fetal head at term.

The complete data of this study are shown in table 7. This table includes the individual measurements of 10 head dimensions of 27 fullterm infants ranging from 48 to 53.5 cm and averaging 50.5 cm in total or crown-heel length. The method of selection of the cases, we think, eliminates to a large degree the error introduced by birth

TABLE 7

MEASUREMENTS OF UNMOULDED HEADS (MM.)
(LIVING INFANTS)

Period of Development	Name	Sex	Age in Hours	Parity of Mother	Method of Delivery	Crown Heel Length	Head Diameters					Head Circumferences					Palpable Moulding
							OF	BiP	SOB	SOF	OM	HHC	SOBC	SOFC	OMC	LC	
Premature	Be	M	29	?	S.	394	101	79	88	95	96	290	271	277	257	307	None
	716	M		?	Post.	396	96	77	88	89	95	272	258	262	248	289	" (Dead)
	Wi	M	28½	I	C.S.	470	111	90	100	103	105	326	305	310	283	330	"
	Br	F	1	VII	S.	475	116	88	96	106	115	324	295	315	295	335	Very slight
	We	F	2	I	S.	475	112	87	97	102	106	320	297	307	277	330	Slight, transverse
Mature	Pa	F	4	I	S.	480	118	89	95	103	115	338	305	312	310	345	None
	Es	M	6½	IV	C.S.	485	126	103	109	118	117	360	339	349	335	387	"
	McA	M	1½	?	S.	490	124	93	104	113	120	355	320	331	310	360	Slight, ant.-post.
	Fi	F	25½	I	S.	490	122	91	99	110	111	338	307	319	291	355	Slight
	Ca	F	1½	V	S.	490	117	95	102	112	115	334	320	326	310	350	None
	Mo	M	3½	I	S.	490	124	93	105	114	121	351	324	331	280	360	Slight
	Br	M	7	II	C.S.	495	119	94	104	112	124	334	308	327	306	360	None
	Wo	M	3	I	S.	498	122	101	100	112	118	355	330	335	310	358	Slight, ant.-post.
	Bra	M	½	I	S.	500	123	102	97	111	125	365	325	346	333	385	Little, ant.-post.
	Sa	F	2	I	S.	500	117	102	107	111	120	347	318	342	322	367	None
	O'N	M	7½	V	S.	500	124	93	106	116	119	345	330	334	325	360	"
	Ga	M	19½	I	S.	500	118	97	103	109	115	342	319	325	318	358	Slight, ant.-post.
	Gr	F	5	?	S.	500	123	101	108	110	125	353	322	328	312	382	None
	Sw	M	10	?	S.	505	114	97	104	112	114	343	326	328	312	354	Slight, ant.-post.
	O'C	M	1	II	S.	505	129	97	108	116	116	358	332	340	310	365	None
	Su	F	6½	?	S.	506	125	98	108	122	127	363	339	355	346	377	"
	Al	M	6½	IV	S.(t.)	510	121	92	105	115	113	347	327	335	302	342	Slight, transverse
	As	M	1½	II	S.	510	123	101	102	111	125	358	330	338	335	379	" , ant.-post
	Cl	F	13	I	S.(t.)	510	125	95	102	114	121	347	317	335	310	355	None
	Ba	M	23	?	S.(t.)	515	128	100	114	120	120	366	342	351	320	375	"
	Fe	F	¼	VI	S.	515	121	98	103	114	120	352	327	340	310	362	"
	Go	M	6½	III	C.S.	520	120	101	104	113	124	357	347	354	305	380	"
	It	M	4	VI	S.	520	117	102	108	113	115	354	340	348	327	383	Slight, ant.-post.
	En	M	2	I	S.	520	115	91	106	110	116	330	318	325	312	350	None
	Wo	M	21½	V	S.	525	116	94	100	112	117	339	323	334	317	357	"
	Ki	M	3½	I	S.	528	132	104	110	115	123	375	345	348	332	384	Slight, ant.-post.
	Gra	F	14	I	S.	535	137	106	119	127	126	385	367	373	320	400	" " "
Average Newborn			8⅙			505	122	97	105	114	119	352	328	337	316	366	
Postmature	Ra	M	7½	I	S.	570	124	103	109	117	125	365	341	355	322	385	Moderate, ant.-post.

moulding so that the resulting averages represent a close approximation to the fullterm head in utero, and may be used as a standard for the correction of our data obtained from stillborn material. These average values show a distinct departure from the figures that are obtained from measurements made some time after birth, which are those usually quoted in texts of obstetrics. We think, however, that they approach more nearly the actual measurements of the fullterm fetus in utero since the cases upon which they are based have not been subjected to moulding, nor have they been increased by growth in the period between birth and the fourth day, when many of the published figures were taken. These dimensions also show a marked departure from our observed figures for head dimensions in fresh, stillborn, fullterm children. The head diameters of the living infants were increased over those of the fresh dead material from 0.2 mm in the case of the occipito-mental diameter, to 10.6 mm in the case of the suboccipito-frontal diameter. The average increase of the 5 diameters studied was 7.5 mm. The circumferences were similarly increased from 9.5 mm in the case of occipito-mental circumference, to 27.5 mm in the case of the horizontal head circumference, the average enlargement of the 5 circumferences being 19.2 mm. It is quite possible that some of the other dimensions of the cranial vault and the base of the skull are affected to a slight degree by the process of birth moulding, although we were unable to include them in this study. So far as this rather small series of cases indicates, there is no direct relation between parity or sex and the degree of cranial change at birth. The exact amount of change in each dimension, and the application of these data to our figures will be considered in detail in later sections of this study.

e. Modifications of the form of the thorax that accompany the partial or complete establishment of respiration.—While the effects of birth moulding on the form of the head have been recognized by obstetricians for a long period, little attention has been paid to birth changes of the external dimensions in other parts of the body. The most striking of these are changes in the form of the chest, which have been described by Scammon and Rucker ('21). These authors estimated that there was an average increase in the circumference of the thorax at the nipples of approximately 2 cm or nearly 9.4 per cent within fifteen minutes after respiration was established. A similar, although less marked, change probably occurs in the circumference at the xiphi-sternal junction and at the level of the tenth rib. After this initial expansion there is a secondary decrease in chest circumference, which begins in the first day and continues to the third day after birth. There is also a corresponding augmentation of the antero-posterior and transverse diameters of the chest, but the former is much the more increased, so that the thoracic index at the level of the nipples rises from about 86 to 106 in the first quarter of an hour of postnatal life. These changes not only modify the form of the thorax in the newborn but they also have an effect on the data on the fetal chest as well, for, although we are accustomed to consider most fetal material as stillborn, Noback ('21) found that 28, or nearly 64 per cent of an unselected series of 44 fetuses of 30 cm and over in total body-length, showed definite evidences of some degree of establishment of respiration.

III. Analysis of Data by Graphic and Numerical Methods

Data of the kind under consideration are of such a complex type and are so influenced both by natural or "gratuitous" variation and by various experimental errors that their significance can be determined only by systematic analysis, preferably by the use of both graphic and numerical methods. Our program for this part of the study included the following steps:

1. Establishment of preliminary tables for each dimension on the basis of the total or crown-heel length.
2. Graphic expression of the distribution of observations of each dimension on the basis of crown-heel length, and establishment of preliminary "point to point" curves based on averages.
3. Correction of preliminary curves for experimental error.
4. Establishment of final curves and development of their expressions by empirical formulae.
5. Computation and compilation of final tables including calculated values, deviations of calculated from observed values, calculated values at 5 cm intervals of body-length, and absolute and percentage increments in these intervals of body-length.
6. Computation of the growth of the external dimensions of the body with respect to age in the fetal period.
7. Computation of relative values on the basis of the total or crown-heel body-length.
8. Computation of ratios or indices.

9. Computation of the values of the external dimensions of the body in the fetal period in terms of their natal values.

10. Construction of histograms illustrating the relative and absolute changes in the external body-form in the fetal period.

11. Graphic and tabular comparisons of the present findings with those of other investigators in this field.

In the following pages these procedures will be described in some detail.

1. Establishment of Preliminary Tables

Practically all the data were collected before any effort was made to analyze them. Primary tables were then made by first arranging the data for each dimension in eleven groups on the basis of the crown-heel lengths of the specimens. Each of these groups represented a 5 cm interval of crown-heel length, the first interval including all specimens below 5 cm and the last all specimens between 50 and 55 cm. The average, the median, the minimum, and the maximum measurement in each interval was then determined and recorded. The average and the median crown-heel length and the average crown-rump length of each 5 cm group of specimens were also computed separately for each dimension. The results of these calculations, with the exception of the median crown-heel lengths and the median dimensions, are given in the second to sixth columns, inclusive, of the tables given in the sections forming the summary of findings (see, for example, table 10, page 76).

2. Graphic Expression of Distribution of Observations

A field graph was constructed for each dimension. In all of these graphs the ordinate or Y axis represented the dimension in question and the abscissa or X axis the crown-heel length of the body. Each observation was indicated on the graph by a symbol, the female specimens being represented by circles, the males by solid dots, and the cases of unknown sex by crossed circles. After the individual cases had been located, the measures of central tendency—the average and the median values for the dimension for each 5 cm interval—were also indicated on the graph by special symbols. The positions of these averages with respect to the X axis were determined by the average body-lengths for the intervals and the positions of the medians by the median body-lengths of the intervals. Two preliminary curves of central tendency were then established on the graph, one by connecting with a set of straight lines all the average points, and another by similarly connecting all the median points of the 5 cm intervals.

3. Correction of Preliminary Curves for Experimental Error

As has been pointed out in a preceding section, a number of dimensions are affected by different artifacts of various origins. The next step in the procedure was to apply to the raw data the corrections obtained by experimental study in order to eliminate these errors as far as possible. Since several kinds of experimental error may affect the measurements of a single dimension, the various dimensions were grouped for consideration according to the effects of artifacts upon them rather than the methods of eliminating each kind of artifact, throughout the series of dimensions.

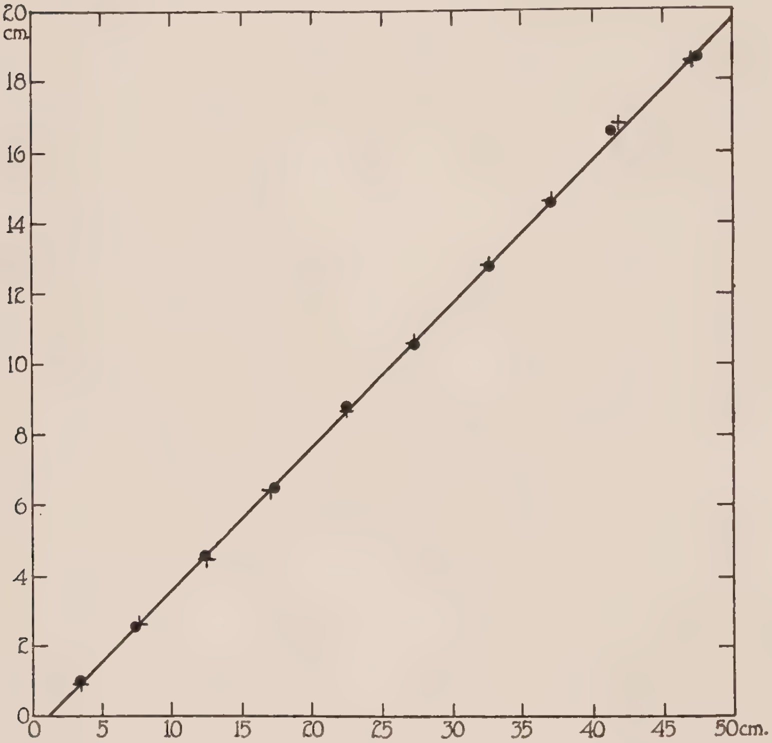
Of the 70 dimensions measured, 19 showed no evidence of any marked influence by artifacts, and the point-to-point curves made by connecting the 5 cm range averages followed the approximate course of a straight line, with respect to total body-length, aside from slight compensatory fluctuations such as are encountered in all large series of measurements of variable objects. An example of this type of dimension is shown in figure 6, which is a graph of the length of the upper extremity plotted against total or crown-heel body-length. The 5 cm interval averages are indicated by dots and the 5 cm interval medians are indicated by crosses. The straight line through these points has been drawn by inspection, and shows how small the deviations are in the trends of this group of measurements. The dimensions of this type were, in the great majority of cases, measurements of distances between skeletal points. They included all of the lengths of the extremities and their parts, measurements of the face and base of the skull, and measurements of two skeletal segments of the trunk.

The remaining 51 dimensions all showed some evidence of being influenced by artifacts, although in no case was this evidence present in the first part of the preliminary curves, which consistently followed a regular course up to at least 30 cm, and in most instances to 40 cm, crown-heel length. The upper portions of these graphs, however, showed some deviations, either upward or downward, from the preceding regular segments of the curves.

In other words, the lower four-fifths of the distributions, which includes the cases much less affected by the factors incident to birth, and which *were not injected but only immersed in formalin, showed an arrangement of the points of central tendency in a regular course with no more deviation than is to be expected in any extended series of measurements of variable material. Irregularities in the plotted measures of central tendency are, in general, found only in the upper fifth of the distributions of material according to crown-heel length, which segment includes the cases largely affected by birth processes, and by neonatal changes, and which includes the material that was injected as well as preserved in formalin.*

FIGURE 6

THE RELATION BETWEEN THE LENGTH OF THE UPPER EXTREMITY AND THE CROWN-HEEL LENGTH IN THE FETAL PERIOD



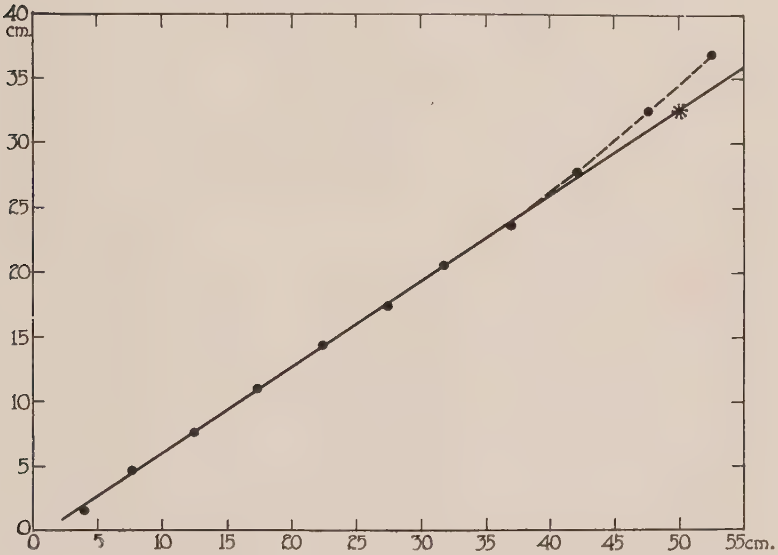
Abscissa: Crown-heel length (cm). Ordinate: Length of the upper extremity (cm). The average values for the 5 cm intervals of crown-heel length, from 0 to 50 cm, inclusive, are indicated by dots, and the medians for these intervals are indicated by crosses. The curve is drawn by inspection.

There were 16 dimensions in which the terminal segments of the distributions were quite evidently primarily affected by injection and subsequent preservation in 10 per cent formalin. This error was shown graphically in our preliminary point-to-point curves, for while the 5 cm interval average points fell in definite alignment up to 30 to 40 cm of crown-heel length, they became much more irregular above this level, falling out of line with the preceding ones, and indicating a marked increase in the measurement. The deviations of these upper points from the course indicated by those of the lower segments of distribution showed a very close relation to the increase produced by formalin injection and preservation as determined by our experimental study of these artifacts.

An example of the condition is shown in figure 7, which is a graph

FIGURE 7

The Relation between the Bi-Deltoid Circumference and the Crown-Heel Length in the Fetal Period



Abscissa: Crown-heel length (cm). Ordinate: Bi-deltoid circumference(cm). The average values for the 5 cm intervals of crown-heel length, from 0 to 55 cm, inclusive, indicated by dots. The broken line is a point-to-point curve drawn through the averages for the last three 5 cm intervals. The solid line is a curve drawn by inspection through the averages for the first nine intervals and projected through the last two intervals. The asterisk indicates the observed value at 50 cm crown-heel length after correction for the artifacts of formalin injection and preservation.

of the bi-deltoid circumference plotted against the total or crown-heel length. It will be seen that the 5 cm interval averages, from 4 to 37 cm, fall approximately in the course of a straight line, while above

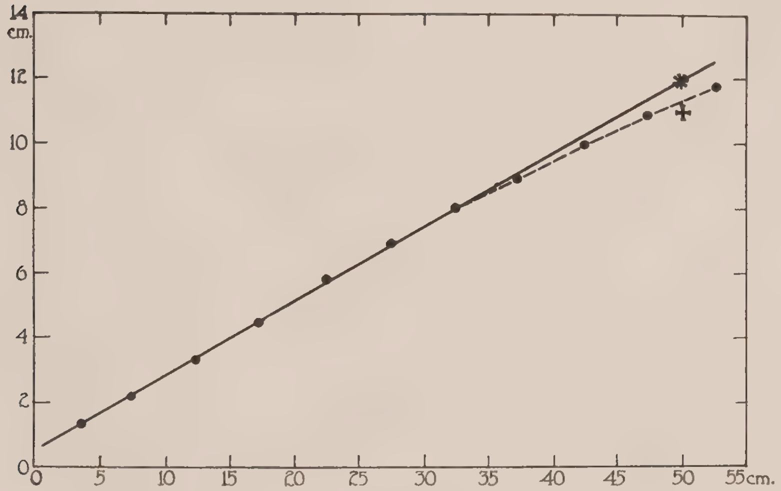
37 cm the slope of the curve, which is indicated in broken line on the graph, is suddenly and distinctly increased. The experimentally determined correction for injection and preservation error of this dimension is 8.9 per cent. This correction, when applied at 50 cm crown-heel length, gives the value indicated by an asterisk on the graph. If now the straight line indicated by the average points from 4 to 37 cm, inclusive, is projected to the upper end of the graph it is found that it passes through the corrected value at 50 cm. This projection is represented by the solid line in the figure. Thus, after removing the artifactual error present in the larger specimens of our material, the resulting values fall in line with the regular course of the points of central tendency of the lower portions of the distribution where this error was not present because these specimens were not injected. The final curves then may be established by the use of these corrected values for the upper portion of the distribution together with the lower uncorrected points of central tendency. This method was used for each of the 16 curves of this group. These include the pelvic dimensions, the crown-rump or sitting-height, the circumferences of the extremities, with one exception, and a few dimensions of the trunk.

There were 16 dimensions of the head that were evidently affected both by birth moulding and by injection. These dimensions were, in whole or in part, measurements of the cranial vault and included 10 of the ordinary obstetrical dimensions and 6 other measurements less frequently studied. The deviations found in the preliminary graphs of this group of dimensions were the reverse of those of the preceding group. The average points above 30 to 40 cm crown-heel length fell *below* the projected line through the lower points, in spite of the fact that our experimental data indicated that the dimensions were increased with injection and preservation. This discrepancy indicates either that the rate of growth of these dimensions, in relation to body-length, undergoes a marked diminution in the last months of prenatal life, or that head moulding decreases these dimensions more than injection and preservation increases them. It was for the purpose of solving this question that the measurements on unmoulded heads, described in a preceding section, were made. When the average values for these dimensions of the unmoulded head, as determined by this special study, were plotted on the several graphs, it was found that they fell within 1 mm of the straight line projected upwards from the points of central tendency for the 5 cm intervals of the lower part of the curves.

An example of this type of dimension is shown in figure 8, which is a graph of the occipito-frontal diameter of the head plotted against the total or crown-heel body-length. The 5 cm interval average points of the observed data are indicated in solid dots and the broken line at the upper end of the graph indicates the depressed terminal segment of the preliminary point-to-point curve through the uncorrected data. The cross on the 50 cm line represents the value at 50 cm, corrected for injection and preservation, and the asterisk on the same line indicates the value of the dimension as measured on unmoulded heads. The solid line is one passing through the lower points of central tendency and projected to the upper end of the

FIGURE 8

The Relation between the Occipito-Frontal Diameter and the Crown-Heel Length in the Fetal Period

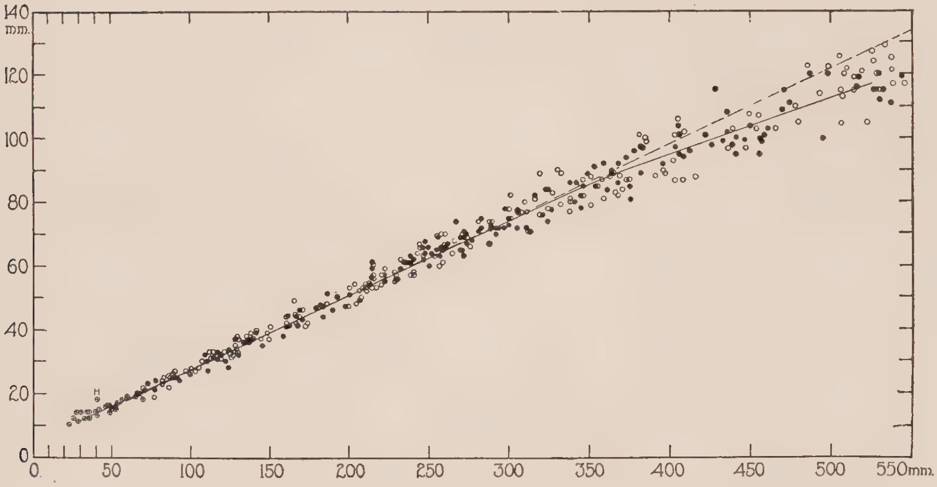


Abscissa: Crown-heel length (cm). Ordinate: Occipito-frontal diameter (cm). The average values for the 5 cm intervals of crown-heel length, from 0 to 55 cm, inclusive, indicated by dots. The broken line is a point-to-point curve drawn through the averages for the last four 5 cm intervals. The solid line is a curve, drawn by inspection, through the averages for the first eight intervals and projected through the last four intervals. The cross represents the observed value at 50 cm after correction for formalin injection and preservation. The asterisk represents the observed value after correction for formalin artifacts and birth moulding.

graph. It shows the correspondence of the extrapolated portion of the curve and the experimentally determined (unmoulded) values at 50 cm crown-heel length. Thus, in this instance, as in the case of the preceding group of curves, correction of artifacts in the upper part of the distribution gives values that fall in line with the course of the uncorrected points of central tendency of the lower portion of the distribution where these artifacts are not present.

FIGURE 9

The Distribution of Individual Observations of the Occipito-Frontal Diameter in the Fetal Period Plotted against the Crown-Heel Body-Length



The curve drawn by solid line represents the point-to-point curve of the averages for this dimension for the 5 cm intervals of crown-heel length, from 0 to 55 cm, inclusive. The broken line represents the projection of the lower segment of this curve as a straight line above 35 cm crown-heel length. Solid dots, males; circles, females; crossed circles, specimens of unknown sex. "H" indicates a hydrocephalic specimen.

This graphic test was made on the 10 obstetrical dimensions of the head and gave the straight line correction in every case. The other 6 dimensions, which showed this same downward deviation, although to a less marked degree, and which also involved the cranial vault, in whole or in part, were found qualitatively to be affected in the same manner by the same artifacts. Therefore, although these dimensions were not measured on unmoulded heads, the same type of correction was applied to them by projecting the line of the lower unaffected and uncorrected average points. The final curves for this group of dimensions were established, as in the preceding group, by the use of corrected values for the upper portion of the distribution together with the lower uncorrected points of central tendency.

There were 9 dimensions that were apparently affected both by formalin artifacts and by neonatal changes associated with the establishment of respiration. These dimensions were all measurements of the trunk and particularly of the thorax. When the 5 cm interval average points of these measurements were plotted against the crown-heel length, they all showed the same general character. They all fell in the course of a straight line up to 40 to 45 cm crown-heel length, but above 45 cm they showed a sudden departure from the trend indicated by the lower values. After the values of these dimensions at 50 cm of crown-heel length were corrected for the effects of formalin injection and preservation, they still showed deviations from the projected line of the lower range averages, as indicated in table 8.

TABLE 8

DEVIATIONS OF THORACIC DIMENSIONS AFTER CORRECTION FOR FORMALIN ARTIFACTS

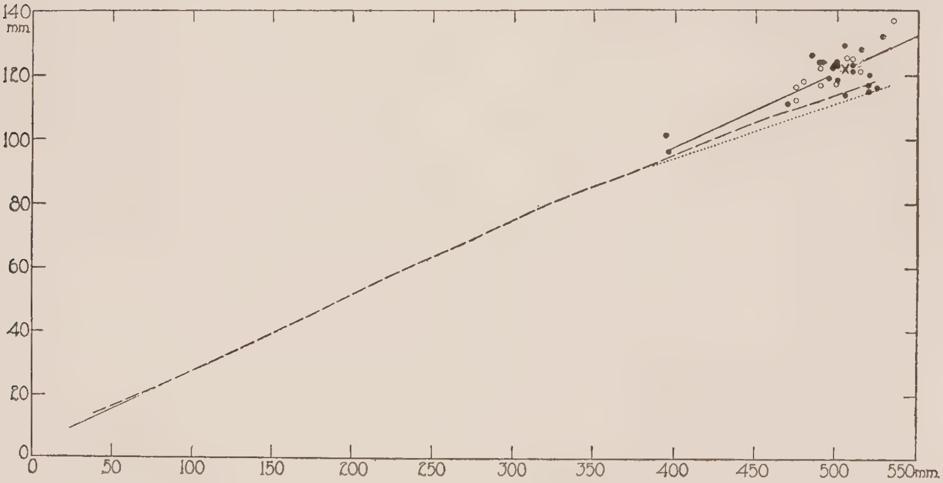
LEVEL OF MEASUREMENT	DIMENSIONS AND DEVIATIONS AFTER CORRECTION FOR FORMALIN ARTIFACTS		
	Circumference (mm)	Transverse diameter (mm)	Antero-posterior diameter (mm)
Nipples	−23	−7	−10
Xiphi-sternal junction	−20	±0	− 5
Tenth rib	−19	+4	− 1
Umbilicus	−12	+8	± 0

This table shows that, with one exception, the 6 true chest dimensions are smaller after correction for formalin artifacts than might be expected from their course of growth in the greater part of the fetal period. This indicates either that the rate of growth of the chest undergoes a sudden and pronounced decrease in the latter part of the fetal period, or that some artifact has caused a diminution in the size of the thorax that nullifies a part of the increase in size introduced by injection and preservation.

That the latter is the case seems indicated by the following evidence: In the study of Scammon and Rucker ('21) on the external dimensions of the chest in the neonatal period, described in a preceding section, it was shown that, while there was an increase in the chest dimensions with the establishment of respiration, this change was followed by a marked decrease in the various measurements of the thorax concomitant with the postnatal weight loss. The decrease in the thoracic circumferences at the levels of the nipples, the tenth rib, and the xiphi-sternal junction, averaged approximately 2 cm. If this further correction of 2 cm is applied to the circumferences, after correction for formalin artifacts, at 50 cm, the resulting value falls directly in line with those observed for the straight portion of the curve. Figure 11, which is a graph of the circumference at the tenth rib, illustrates this procedure. The solid dots of this graph

FIGURE 10

The Effect of Birth Moulding on the Occipito-Frontal Diameter in the Latter Part of the Fetal Period

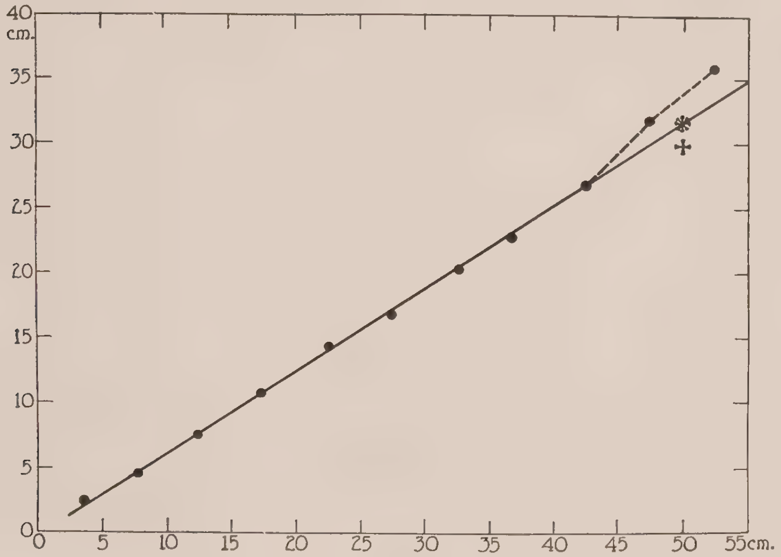


Abscissa: Crown-heel length (mm). Ordinate: Occipito-frontal diameter (mm). The broken line is a point-to-point curve of the averages of this dimension for 5 cm intervals of crown-heel length, from 0 to 55 cm, inclusive. The dotted line represents the position of the upper segment of this curve after correction for the artifacts of formalin injection and preservation. The dots and circles represent observations of this dimension on living unmoulded heads and the cross is the average of these observations. The solid line represents a projection of a straight line for the observed averages of the eight lower 5 cm intervals of this series projected through the three upper intervals.

indicate the positions of the uncorrected 5 cm interval averages. It will be seen that these follow the course of a straight line up to 42.5 cm, but that the last two show a distinct upward deviation. The cross on the graph indicates the value at 50 cm of crown-heel length after correction for formalin artifacts. It therefore represents the true value for uninjected fetuses at 50 cm. The asterisk on the graph indicates the value at 50 cm, after adding the 2 cm correction for neonatal thoracic changes described by Scammon and Rucker. It will be seen that this symbol lies directly on the line projected through the averages of the lower straight portion of the curve. In other words, after correction of the upper observed values for formalin

FIGURE 11

The Relation between the Circumference of the Abdomen at the Tenth Rib and the Crown-Heel Length in the Fetal Period



Abscissa: Crown-heel length (cm). Ordinate: Circumference at the tenth rib (cm). Average values for the 5 cm intervals of crown-heel length, from 0 to 55 cm, inclusive, indicated by dots. The broken line is a point-to-point curve drawn through the averages of the last three 5 cm intervals. The solid line is a curve drawn by inspection through the averages for the first nine intervals and projected to 55 cm crown-heel length. The cross represents the average observed circumference at 50 cm crown-heel length after correction for formalin injection and preservation artifacts, and the asterisk represents the observed value at 50 cm crown-heel length after correction for the changes produced in the establishment of respiration.

artifacts and for the neonatal dimensional change, a value is obtained that is comparable with the values for the earlier ranges where these artifacts have little influence, since the smaller specimens are generally truly stillborn, are not injected, and are placed in preservative immediately after delivery. This, in our opinion, indicated a continuation of the rectilinear type of curve through the last two 5 cm intervals of crown-heel length to the end of the fetal period.

The other thoracic circumferences treated in the same manner give the same results. The antero-posterior and the transverse diameters of the chest at these levels present the same type of curve as these circumferences, are affected in the same general way by injection, and are subject to the same type of postnatal decrease. However, the injection correction, as determined by our experimental study, does not entirely compensate the artifacts of these dimensions because of the flaccidity of the material, which increases the transverse diameters. But when these corrections were made, the results approximated straight lines so closely that we felt entirely justified in considering them as such.

There remain 10 of the 70 dimensions, which may be subdivided into two groups of 5 each. The first of these groups comprises 5 anterior longitudinal midline measurements of the trunk. The first portions of these curves showed the regularity characteristic of the other parts of the body, but their upper segments showed marked deviations, which were only partially accounted for by injection artifacts. These dimensions were all influenced by posture, and we think it probable that this is the chief factor causing their change in slope; for another measurement of the same type but of a skeletal part—namely, the length of the sternum—did not present these peculiar deviations. However, since we did not make a quantitative experimental study of the effect of posture, we have not felt justified in attempting its correction and, therefore, have only eliminated the injection and preservation error from the average points of the upper segment of the distribution by the methods described in the preceding pages. As will be noted in the next section, the resulting curves are not straight lines.

The last 5 curves form a heterogeneous group in which each shows its own peculiarities.

The distance between the nipples shows a marked deviation upwards of the last two 5 cm interval averages, which is not corrected by the figures for formalin artifacts. This may be a chance deviation in somewhat variable material, but it is more probable that it represents a natal enlargement of the breasts accompanying the formation of "witch's milk." Below the last two 5 cm interval averages the approximation of this dimension to a straight line is a very close one, and we have therefore extrapolated this curve to the end of the fetal period.

Our technique of measurement was at fault in determining the biauricular diameter, for the measurements of the older specimens were made with a rounded-point pelvimeter, while those of the younger ones were made with flat-bar calipers. Consequently there is a slight modification in the slope of the preliminary curve at about 25 cm crown-heel length where the change in technique was made. The lower segment of the curve is a straight line without correction. The upper segment of the curve is also a straight line, of a slightly different slope, after correction for formalin injection and preservation.

The thigh circumference shows a marked deviation upward in the last two 5 cm interval averages. After correction for formalin artifacts there still remains a slight deviation (of about +3 per cent in the last 5 cm interval average). This deviation may possibly be due to an increased deposition of fat in certain fetuses in the last days of prenatal life or possibly to differences in the posture of the thigh in the larger specimens.

The distance from the crown to sternal notch is probably affected by a complex of artifacts consisting of an injection and preservation error, head moulding, respiration change, and a postural modification similar to that affecting the other anterior longitudinal measurements in the midline. The data on this measurement have been corrected for formalin artifacts, but no further correction has been attempted.

The circumference of the neck is quite regular up to 35 cm crown-heel length. Above this point the 5 cm interval averages show a rapid rise, but this rise is much more than compensated by the formalin correction. This dimension is so variable in larger fetuses and is so easily affected by postural change, birth engorgement of the cervical veins, technical difficulties in making the measurement at a constant plane, and thyroid enlargement (in this district), that we regard our figures as quite unreliable, although we have represented the course as a straight line in the last two 5 cm intervals on the basis of our averages for the lower segments of the distribution.

4. Establishment of Final Curves and Development of Their Expressions by Empirical Formulae

The field graphs were now provided with a new set of points of central tendency giving corrections, where required, for the main artifacts in the observed data. These graphs were again examined and new curves of central tendency were drawn on them by inspection. In this process we made use of the corrected average points, and, for the lower parts of the curves, of the weighted median points as well. Usually, however, the average and median points lay so close together that the use of the latter seemed superfluous (see figure 6). The empirical formulae for these curves were then determined by standard graphic methods.

The purposes of developing graphic empirical formulae for these curves are several. The procedure does not increase the reliability of the inspected curve nor does it improve the accuracy of the points upon which it is based, but it does give an accurate and abbreviated expression of the curve as drawn, allows a numerical statement of the differences between the observed and inspected values, affords a quick and accurate method of interpolation, and is particularly valuable in shifting sets of values into different scales and forms of expression. It is also useful in classifying curves as to form and character, but it should be remembered in this connection that the reliability of the deductions made by this method is dependent on the amount of error in the original observations and in the estimation of the curve drawn through them.

It was found that 64 of the 70 dimensions studied approximated straight lines when plotted against the total or crown-heel body-length and that therefore they might be expressed by the general equations:

$$Y = aX + b.$$

Y in these equations is the dimension in millimeters, X is the total body-length in millimeters, a is a constant in the form of a decimal fraction, and b is a second constant in millimeters.

The remaining 6 dimensions could not be expressed by formulae of this simple type. Of these, 5 were the measurements of distances in the median line of the anterior surface of the body, which have just been discussed. They showed a variety of forms. Four were represented by straight line formulae, which were phased at 25 cm total body-length. The fifth curve was also phased at 25 cm, but the formula for the first segment of the curve involves a fraction of the square root of the body-length. It may be said that while the formulae for these 5 curves give approximate expressions of the data as observed and corrected for formalin artifacts, we think that further study of artifacts, and particularly of the flexion of the body, may lead to some changes in them, possibly to reducing them to simple straight line formulae. The sixth was the bi-auricular diameter, which was also bi-phased as two straight lines. As pointed out in the preceding section, the peculiarity of this curve is probably due to a change in the technique of measurement of the larger specimens.

Empirical expressions and curves for these progressions were also developed by the method of averages and the method of least squares. The method of averages or means gives an expression (for a rectilinear progression) by which the algebraic sum of the deviations of the calculated from the corresponding observed values is zero. In determining the constants of the empirical formulae by this method we have made use of all the observed means for 5 cm intervals of total body-length where the dimensions were not obviously affected by artifacts. In instances where artifactual errors were demonstrated to affect the upper part of the progression, the expression was developed by use of all the means of the 5 cm intervals in the lower and unaffected part of the progression and one value in the upper segment of the progression. This last value was corrected for all artifacts by use of the factors discussed in the preceding section. The number of values used in fitting each formula are shown in table 163. All of the fits were made to the means unweighted by the number of observations included in them. This was done because the number of observations in the 5 cm intervals of the lower part of the progression is fairly constant and because we had no rational method of assigning a weight to the upper, corrected value.

The method of least squares gives an expression by which the sum of the squares of the deviations between the observed and corresponding calculated values is set at a minimum. Our procedure in applying this method to the material was the same as that used for the method of averages.

Obviously no exact comparison can be made of the fits of the formulae derived by these various methods, for the criteria of goodness of fit differ for each of them. The graphic method is a procedure that depends essentially on the experience and judgment of the computer. The method of averages is more automatic, although there still remains an element of choice since its development involves the use of two segments of the progression (to obtain the two constants of the formula), and these may be modified by the computer. The method of least squares is entirely automatic and is the more generally accepted one. But its use in this instance was complicated by the necessity of using a single corrected point in the upper part of the progression of dimensions affected by artifacts.

Some general summaries of these formulae are included in the tables at the close of this monograph. Table 163 shows the empirical constants, as determined by the three methods and the number of points used in the determination of each formula, and table 164 gives the mean absolute and mean percentage deviations, with and without regard to sign, of the calculated from the corresponding observed values. Table 165 gives the root mean square deviations of the calculated from the observed values, with and without the inclusion of the means affected by artifacts. It will be seen that the constants obtained by these three methods are usually in fair agreement.

The fits of the expressions for these relationships, when determined by the methods of averages and of least squares, were made to the mean values for 5 cm intervals of body-length. An estimate of the validity of fitting to the means for these intervals, without regard to the variability of the individual observations, may be made by a "deviation ratio," when the rectilinearity of the relationship and the least square criterion of goodness of fit are accepted. In this case the line of regression of the dimension on body-length is the theoretically true expression of the relationship involved and the variation about the line is at a minimum. The "deviation ratio" (DR) is an expression of the degree to which the variability about the given line approximates this minimum. Incidentally, the ratio gives an idea of the closeness with which the given line approximates the regression line.

If the root mean square deviation of the ordinates of the individuals about a line is represented by s, DR may be written in the form s_1/s_0 where the subscripts *1* and *0* indicate any line and the line of regression, respectively. More analytically:

$$DR = s_1/s_0 = \frac{\sqrt{\sigma^2 y + a^2\sigma^2 x - 2a\sigma_x\sigma_y r + (b + a\bar{x} - \bar{y})^2}}{\sigma_y\sqrt{1-r^2}}$$

where $\bar{x}$ and σ_x represent the mean and standard deviations, respectively, for the measurements of body-length, similarly $\bar{y}$ and σ_y, for the measurements of the dimension, r is the Pearsonian coefficient of correlation between the two variates, and a and b are the constants of the line $y = ax + b$ with which the comparison is made.

For the practical determination of s_1 and s_0 the individuals were grouped in small cells designed to come within the experimental errors of measurement. As a general test of the material comprising 70 sets of measurements these ratios were computed for the 3 different fits (by the graphic method, by the method of averages, and by the method of least squares) for the 6 most variable and the 6 least variable sets of data. The results are recorded in table 166. They indicate that with the exception of the graphic line for the forearm length, there are no appreciable differences among the several fits as obtained by the three methods. With the further exception of the occipito-frontal diameter, they show no appreciable differences between the results of any one of the different methods of fitting and the regression line. It is difficult to estimate the significance of the ratio 1.81 in the latter exception.

The above comparisons were based entirely on the lower portions of the progressions. The s_1's were also compared for the data corrected and the data uncorrected for the upper portions of those progressions where artifactual corrections were necessary. In these cases it was necessary to measure graphically the deviations from the lines. Also the graphic line only was used, for the fitted lines were practically coincident in all these instances. The results are shown in table 167. They support, in every instance, the conclusion already drawn that the data corrected for artifacts fit more closely the projection of the trend of the lower portion of the line than do the uncorrected data. It will be noted that the s_1's, both for corrected and uncorrected data, are conspicuously larger than the corresponding s_1's for the lower portions of the curves. It is doubtful if this is indicative of a significant deviation of trend, for the number of cases is not comparable, and there is an increase in variability along the progression, although we have been unable to obtain a satisfactory measure of it.

5. Computation of Final Tables, Including Calculated Values, Deviations of Calculated from Observed Values, Calculated Values at 5 cm Intervals of Total or Crown-Heel Body-Length, and Absolute and Percentage Increments in These Intervals of Body-Length

After the empirical formulae for the various curves were determined by graphic methods, the calculated values of each dimension for the average body-lengths of each 5 cm interval, from 5 to 55 cm, inclusive, were computed and the deviations of these values from the corresponding observed averages drawn up. These deviations were first computed as absolute values in millimeters and then as percentages of the observed averages. These figures are given in the seventh, eighth, and ninth columns of each table of findings for the individual dimensions. The average absolute and the average percentage deviations for the 5 cm interval values from 5 to 55 cm, inclusive, were also calculated, and these are included in the text of the sections on summary of findings.

It will be noted that both the absolute and the percentage deviations were calculated from the observed averages without the corrections for artifacts. Consequently these deviations are much larger, particularly for the averages of the higher intervals of body-length, than if allowance had been made for these corrections. In other words, these deviations include both the artifactual errors of the data and the errors of curve fitting. While deviations calculated from the corrected, observed averages would appear much smaller on paper, it seems more desirable to have these figures represent the entire departure of the calculated results from the raw data, since comparisons are to be made with the uncorrected data of other observers.

The means of all these deviations and their root mean squares form tables 164 and 165 of Part XII of this monograph.

The empirical formulae as determined by graphic methods were next used to compute the values of the several dimensions at each 5 cm of total body-length from 5 to 55 cm, inclusive, and to calculate absolute and percentage increments of the values between these points. The determination of the absolute increment is only a matter of subtracting the value at the beginning of a 5 cm interval from its value at the end of the interval, or, even more simply, in the instance of the straight line formulae, of multiplying the first constant by 50. In these cases the increment is, of course, constant for the entire series of intervals. The percentage increment was determined in the usual manner by subtracting the value at the beginning of the interval from the value at the end of the interval, dividing the remainder by the value at the beginning of the interval, and multiplying the quotient by 100. In other words:

$$\text{Percentage increment} = \frac{V_2 - V_1}{V_1} \times 100.$$

It should be understood that the percentage increment is used in this study only as another method of measuring the *quantity* of growth in a given interval or period. Its use as a measure of *relative rate* of growth involves several fallacies. These are pointed out by Thompson ('17, p. 72 *et seq.*) and in the various papers forming a discussion on the subject by Briggs, Kidd and West ('20, '21), Blackman ('19), and Fisher ('21), and are well summarized in a recent monograph by Brody ('27).

The calculated values at the 5 cm points and their absolute and percentage increments are given in columns 10, 11, and 12 of the tables of findings of each dimension.

6. Computation of the Growth of the External Dimensions of the Body with Respect to Age in the Fetal Period

All of the preceding calculations are based upon the relations of one external dimension of the body to another, and, in particular, all dimensions have been reduced to expressions as functions of the total or crown-heel length. It is also very desirable to follow the changes in these dimensions in relation to time, but this cannot be done directly with our material since few of our specimens were accompanied with clinical histories from which the age could be estimated with any accuracy. It is possible, however, to develop a convention for expressing the relation of body-length to age in the fetal period based upon the best available data on this subject, and from this to calculate the course of growth of the other external dimensions in relation to time. A convention of this kind will only approximate the truth and may be modified as a result of further studies of this subject, but such an adjustment can be easily made since both time and the various external bodily dimensions are expressed as functions of a single variable—the total or crown-heel length.

In the last sixty years a large number of studies on the relation of the body-length to age in the fetal period have appeared in the literature of embryology and obstetrics. The results are generally summarized in tabular form, although many have been presented graphically and a number of formulae have been developed for their expression.

Since none of the published expressions fully meet our requirements, it seemed best to develop a new formula based on the data now available in the literature. The following conditions were laid down as desiderata for a practicable formula of this kind: first, it must represent the age in months as a function of the body-length in centimeters; second, it must give values that correspond closely to the observed values obtained by the best studies on this subject; third, it must hold good for at least the entire fetal period (three lunar months to birth); and, fourth, it should be preferably of a simple type, which will permit its use without the necessity of recourse to tables of special functions and the like.

To obtain this formula, 18 of the more complete sets of data on body-length and prenatal age, as recorded in the literature, were first laid out on the same graph, time being used as the Y axis and body-length as the X axis. These curves were then carefully compared and it was found that they might be arranged in three main groups. The first group included 8 curves, based mainly on early observations. They were quite irregular, exhibiting marked sinuosities and changes in slope, but otherwise showing little agreement with one another. The second group included 6 curves that in most instances represented only the linear growth changes of the latter part of the fetal period. Most of these represented modern work on living material and were in quite close agreement. The third group included 4 curves representing the observations of Mall ('10), Zangemeister ('11), Heuser ('12), Lacassagne ('09), and Streeter ('20).* These 4 curves, as a group, cover the greater part of the prenatal period, and are remarkably consistent both in their individual courses and in relation to one another. They are the results of independent study by different investigators using modern methods and are based upon carefully selected material. We have therefore regarded them as probably representing more accurately the linear growth of the fetus in respect to time than do the two other groups described above. When this last group of curves was examined in detail, it was found that Mall's curve was the median one in the majority of instances and this, together with the fact that it represented by far the largest group of cases, led us to select it as the basis for our empirical formula.

The curve chosen for a working representation of Mall's data is a parabola having the general form:

$$T = a + bL + cL^2,$$

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* The values employed in drawing the curve used to represent Streeter's data were obtained from his crown-rump lengths by substitution in the empirical formula:

$$CR = 0.66\ CH + 0.5 \text{ cm or } CH = \frac{CR - 0.5}{0.66}.$$

where T is the age in fetal or lunar months of gestation, L is the total or crown-heel length of the body in centimeters, and a, b, and c are empirically determined constants. The specific formula adopted is:

$$T = 2.3 + \frac{2.5L}{28} + \frac{L^2}{784}.$$

This may be simplified to:

$$T = \left(\frac{L}{28} + 1.25\right)^2 + 0.74.$$

Mall's figures were obtained by arithmetic interpolation from his tabulation of his data. The sum of the age deviations for ten 5 cm intervals of body-length from 5 to 50 cm, inclusive, is 0.38 fetal months, and the average deviation is 0.038 months, or very slightly more than one day. This average deviation is probably well within the average error of estimation of the age of the fetus from even the best type of clinical history. The sum of the percentage deviations for the same series is 7.84, and the average deviation 0.78 per cent. The sum of the deviations of the computed from the observed body-lengths, for three to ten months, inclusive, is 1.21 cm, and the average deviation is 0.15 cm. This again is probably within the average error of the physical observation, at least for the larger specimens. The sum of the percentage deviations is 3.85 and the average is 0.48 per cent.

The segment of greatest departure of the observed and calculated curves is between 5 and 15 cm body-length when the observed curve rises distinctly above the calculated one. This rise is not found in the other curves of the group that includes Mall's curve. The formula may be used for specimens between 4 and 55 cm in total body-length.

The relations of Mall's observed values for mean menstrual ages to the computed values obtained by our formulae are shown in table 9 and figure 12.

7. Computation of the Relative Values of the External Dimensions of the Body on the Basis of the Total or Crown-Heel Body-Length

The relative sizes of the several external bodily dimensions at different stages in the fetal period were first expressed as per cents of the total or crown-heel length. These computations were made from the calculated values obtained from the empirical formulae with the constants determined by graphic methods. The ratios were

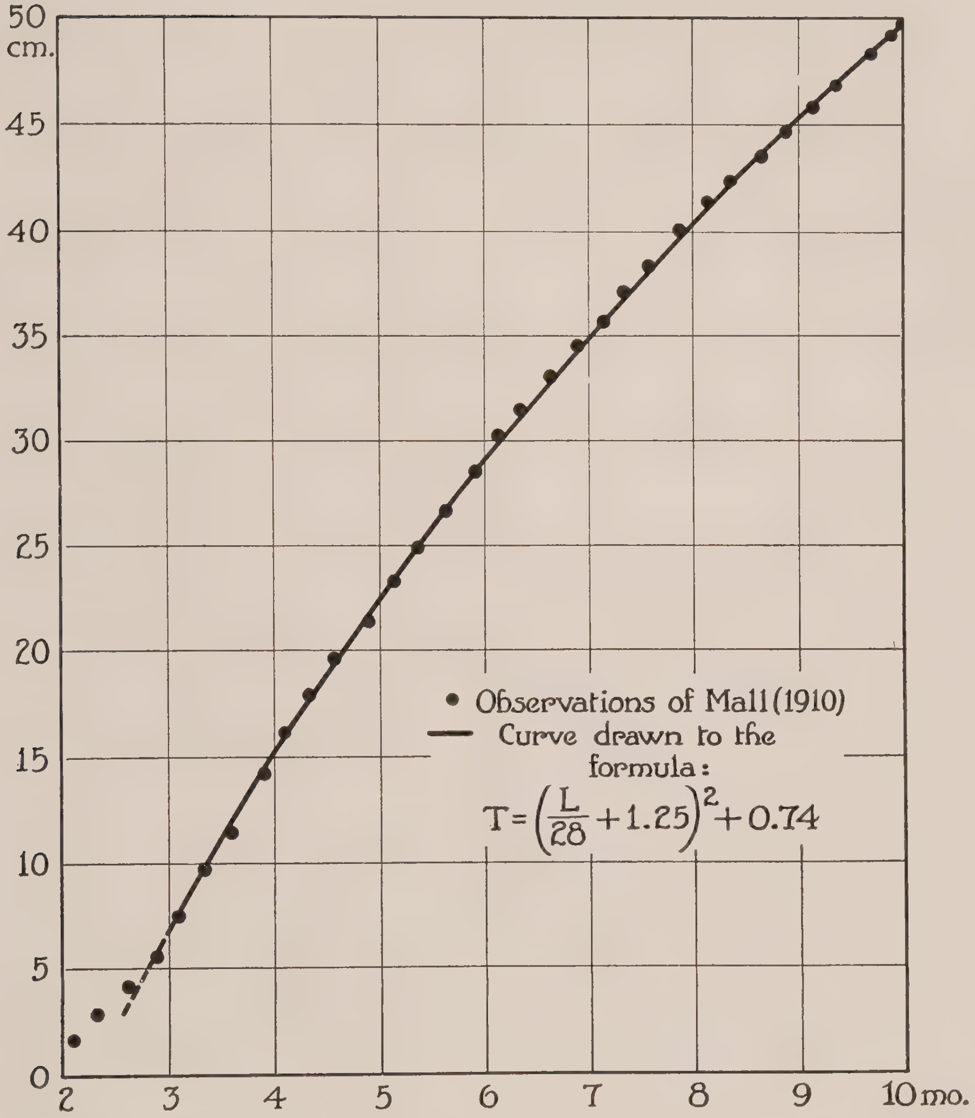
TABLE 9

Crown-heel Body-length and Age in the Fetal Period

Total or crown-heel body-length as given by Mall (cm.)	Mean menstrual age as given by Mall (1910)		Menstrual age as determined by the empirical formula: $T=\left(\frac{L}{28}+1.25\right)^2+0.74$	
	Days	Lunar months	Calculated values (lunar months)	Deviation of calculated from Mall's observed values (lunar months)
7.6	86	3.07	3.05	− 0.02
9.8	94	3.36	3.30	− 0.06
11.7	100	3.57	3.53	− 0.04
14.5	108	3.86	3.87	+ 0.01
16.1	114	4.07	4.09	+ 0.02
18.0	121	4.32	4.31	− 0.01
19.8	128	4.57	4.58	+ 0.01
21.5	136	4.86	4.82	− 0.04
23.3	143	5.11	5.07	− 0.04
25.0	150	5.36	5.32	− 0.04
26.8	157	5.61	5.62	+ 0.01
28.6	165	5.89	5.89	± 0.00
30.2	171	6.11	6.17	+ 0.06
31.5	177	6.32	6.40	+ 0.08
33.1	185	6.61	6.64	+ 0.03
34.5	192	6.86	6.89	+ 0.03
35.8	199	7.11	7.14	+ 0.03
37.1	205	7.32	7.39	+ 0.07
38.4	212	7.57	7.60	+ 0.03
40.0	219	7.82	7.92	+ 0.10
41.5	228	8.14	8.19	+ 0.05
42.5	234	8.36	8.41	+ 0.05
43.6	241	8.61	8.64	+ 0.03
44.8	248	8.86	8.86	± 0.00
46.0	256	9.14	9.09	− 0.05
47.0	262	9.36	9.32	− 0.04
48.4	271	9.68	9.62	− 0.06
49.4	276	9.86	9.80	− 0.06
50.0	280	10.00	9.98	− 0.02

FIGURE 12

THE RELATION BETWEEN THE TOTAL (CROWN-HEEL) BODY-LENGTH AND AGE IN THE FETAL PERIOD



Abscissa: Menstrual age in lunar months of 28 days. Ordinate: Total or crown-heel body-length in cm. The dots represent the mean values given by Mall ('10). The curve is drawn to the empirical formula of Scammon and Calkins ('23).

calculated for each dimension at each 5 cm of crown-heel length from 5 to 50 cm, inclusive. Similar ratios were also determined for the calculated body-lengths at each lunar month of the fetal period. These tabulations are given in the résumés of Parts III to VIII, inclusive, of this monograph, and are discussed and presented in graphic form in these sections.

8. Computation of Analytic Indices for Various External Bodily Dimensions in the Fetal Period

Several students of the anthropometry of the human fetus have expressed their results in the form of indices. In such indices a given dimension is expressed as a ratio or per cent of another given dimension. We think that in the present instance the analytic method, with the use of the crown-heel length as a base, is preferable for the study of relative size. Therefore a series of these indices based upon the calculated values of the dimensions involved at various body-lengths and estimated ages have been computed. These indices do not represent the averages of observed individual ratios but the trends of the various progressions expressed as ratios. While these analytic ratios are not equivalent to the indices based upon individual ratios, they are of the same order of magnitude. We think that the results of the analytic method are more precise because they are computed from central tendencies determined from *all* of the observations in the entire range of the progressions involved, and because they avoid the *added* spurious effects that are associated with the variability of individual ratios when they are treated *en masse.*

Some 120 of these indices have been computed, using the calculated values for the various dimensions as given by our empirical formulae with the constants determined by graphic methods, by the method of averages, and by the method of least squares. These indices were computed for the values at 5, 25, and 50 cm crown-heel lengths, and also for the values at three, six, and ten months, with age estimated from body-length by the empirical formula of Scammon and Calkins ('23). The indices computed from the various types of empirical formulae were, in general, so similar that only those obtained by the formulae with graphically determined constants are published in this study, except for a few special cases. The résumés of Parts III to VIII of this monograph contain a discussion of them.

9. Calculation of Values as Percentages of the Sizes at Birth and at 50 cm of Crown-Heel Length

The methods just outlined deal mainly with the determination of relative values for external bodily dimensions at given body-lengths and calculated ages. It is desirable, however, to introduce one more form of scale for the comparison of the growth of the various dimensions with one another. For this purpose it is necessary to reduce all dimensions to a common standard, and we have therefore considered the value of each dimension at 50 cm of crown-heel length as 100 or unity and have computed the calculated values at each 5 cm interval of body-length below 50 cm as per cents of this standard. This allows a direct comparison of the growth of the dimensions of very different magnitudes. To make a similar comparison in relation to time in fetal months, we have considered the value of each dimension in the newborn as 100 and have computed the calculated values at the end of each fetal month, from the third to the ninth month, inclusive, as percentages of this standard. These figures were arranged in tables, which are included in the résumés of Parts III to VIII, inclusive, of this monograph.

10. Construction of Histograms Illustrating the Absolute and Relative Changes in the External Body-Form in the Fetal Period

To summate our findings in more graphic form we have constructed a series of figures illustrating anterior views of fetuses, one for each 5 cm step of total or crown-heel body-length from 5 to 50 cm, inclusive. To make these a set of form-figures was first drawn up in multiple, and the dimensions, as determined by formulae, were indicated upon them. Well-preserved specimens that approximated the desired body-lengths were then selected from the collection, and these, together with the forms, were turned over to the artist who prepared the drawings, taking care to bring all measured dimensions to the values indicated on the forms. These drawings, reduced to one-fourth the original and natural size, are shown in figure 70. A second set of figures to show the changes in the relative proportions were prepared in the same way, except that they were drawn to a single standard body-length. These are shown in figure 72. Similar sets of drawings were made to represent the relative and absolute proportions at the end of each fetal month from the third fetal month to birth, inclusive. These are reproduced in figures 71 and 73.

11. Graphic and Tabular Comparisons of the Present Findings with Those of Other Investigators in This Field

As pointed out in a preceding section, there are numerous data in the literature on the growth of certain external body dimensions in the fetal period. In order to compare our results with those of other investigators, we have summarized their findings by computing their average values in 5 cm intervals of crown-heel length in the same fashion as our own. We have also computed the average crown-heel lengths in the 5 cm intervals to allow comparison with our material. These results are given in tabular form in tables 168 to 180, inclusive, Part XIII of this monograph. When possible, we have also made graphic comparisons by plotting point-to-point curves of each investigator's data, including on the same graphs our curve as obtained by the empirical formula with graphically determined constants. We obtained sufficient data on fetal growth from the literature to make tabular comparisons of 41 of the 70 dimensions measured. There were enough published data on 30 dimensions to warrant the construction of graphs comparing the results of other authors with our findings.

Tables were also made of various observers' figures for different dimensions in the newborn in comparison with the computed natal values as estimated by our empirical formulae with graphically determined constants. These included 34 of the 70 dimensions, and are given in the summaries of findings.

IV. Scheme Employed in the Presentation of the Summaries of Findings

Parts III to VIII, inclusive, of this monograph, consist of summaries of our findings regarding the fetal growth of various regions of the body and contain much of the foregoing material. The same general plan has been followed in all of these sections. Each summary consists first of an introductory note on the number and nature of the dimensions studied. Each dimension of the region is then considered separately in a digest made up of a brief description of the dimension, an estimate of the artifacts affecting it, a table of observed and computed values for 5 cm intervals of crown-heel length, and a statement of several measures of the average absolute and relative deviations of the calculated values from the corresponding observed means for the 5 cm intervals of crown-heel length included in the progression. *The last statement is limited to the devia-*

tions computed without regard to sign. The root mean square deviations and the deviations summed with regard to sign are given in general tables in Part XII. A statement of the previous published work on each dimension forms a part of each digest. Statements regarding the studies of previous authors on fetal material are given only when their data are classified according to crown-heel length and are therefore comparable with our own. A list of the natal values for each dimension as determined by other authors and as computed in our study is included in each digest. Each summary is concluded by a résumé with graphs, tables, and discussions of the growth of the dimensions of the region with respect to body-length and to time, computations of relative growth, calculated indices, and similar material.

PART II

A SUMMARY OF PREVIOUS STUDIES OF EXTERNAL DIMENSIONS OF THE FETUS AND NEWBORN

I. Introductory Note

Quantitative data on early human growth are of interest in a number of widely separated fields of the medical and allied sciences, and consequently the subject has been investigated independently from several points of view. On this basis, we may group the published studies into four general classes, viz., those associated with legal medicine, with obstetrics and pediatrics, with artistic anatomy, and with embryology, developmental anatomy, and physical anthropology. In consequence of these differences in viewpoint, we find that the methods of investigation vary considerably with different observers and that the publications on the subject are scattered through many widely separated sections of medical and biological literature. Many have appeared as theses or brochures, or are contained in hospital reports and the rather inaccessible transactions of special societies and academies.

Although occasional records of the dimensions of the fetus and newborn are found in some of the medical literature of the latter part of the eighteenth century, the first systematic studies on the subject began a number of years later. These studies were pursued in artistic anatomy, legal medicine, and obstetrics at about the same time. The first systematic account of the external dimensions of the newborn infant seems to be that of Schadow, whose *Polyclet* included a very complete canon for the proportions of the child at birth. Later studies in this phase of artistic anatomy were published by Carus ('54), Zeising ('54), and Liharžik ('58).

The extensive work of Quetelet on the postnatal growth of the body, which includes a very elaborate set of measurements of the dimensions of the newborn, was begun in the first half of the nineteenth century, although his complete tables were not published until much later.

Measurements of the horizontal circumference and the perimeter of the head in a series of 120 newborn children were made as early as 1786 by Joseph Clarke, of London, and a number of averages and ranges of the various obstetrical diameters and circumferences at birth were published early in the nineteenth century. The subject was re-examined in a much more thorough manner between 1860 and 1880 by a number of obstetricians, among whom may be mentioned Grillenzoni ('68), Spiegelberg ('68), Calderini ('75), Sutugin ('75), Budin and Ribemont ('76), Depaul ('79), and Mandelstam ('80). A number of investigations dealing with special phases of this problem have been made since this time. Therefore our knowledge of the growth and proportions of the head in the latter part of prenatal life is more complete than that of most phases of fetal development.

The study of the fetal growth proper, as distinct from the dimensions of the newborn, practically began in the late seventies with Burtscher's ('77) investigation of the prenatal growth of the extremities, Jousset's observations on the growth of the diameters of the head, which were published in the same year, and the appearance of Hennig's graphs in 1879. Little more was added until the publication of the dissertation of Faucon in 1897. Important contributions were made a little later by Corrado ('99), Legou ('03), and Retzius ('04). The work of Retzius has become deservedly a classic in this field. That of Corrado is almost unknown, for it was published in the transactions of a rather obscure local society. It is an extensive and excellent monograph, which deserves far greater recognition. Later important studies have been made by Michaelis ('06), Heuser ('12), Friedenthal ('14), and Streeter ('20). The most recent extensive work in this field is that of Reicher ('23, '25) and of Schultz ('22, '23, '26). The detailed studies of the latter investigator have not as yet been published in full.

Besides these more general studies there have been a number of investigations dealing with the prenatal growth or natal proportions of certain small regions or of individual dimensions. Among these are the researches of Rodes ('06) on the thoracic index, Klein ('96), Konikow ('94), Tatewossoff ('99), and LeDamany ('10) on the dimensions of the pelvis, Gönner ('84) on the foot, Lodoli ('87) on the hand, and Schultz ('20) on the external nose.

In the following summary we have drawn up a series of short digests of the main quantitative studies of external dimensions of the body in the fetal period and at birth that are available to us. These include statements of the number of cases, measurements taken, nature of the records published, and similar data. More detailed accounts of the individual dimensions are given in connection with the latter part of this publication. The majority of these studies deal primarily with the external dimensions of the newborn. Those that are concerned primarily with fetal growth, or that include large amounts of data on this phase of the subject, are indicated in our list by asterisks. We have not included in this summary the general statements of fetal and newborn dimensions that are found in texts of obstetrics and pediatrics, but some of these are given in connection with the summaries of findings.

II. Abstracts of Previous Studies

Ahlfeld ('71). Total body-lengths and bi-temporal and bi-parietal diameters of the heads of 290 fullterm and premature, living children, ranging from 41 to 56 cm in crown-heel length. Data averaged for 5 cm intervals of total (crown-heel) body-length. Sex not indicated. Material from the obstetric polyclinic of Leipzig.

***Akiba ('24).** Data on the total (crown-heel) body-length, sitting-height, orbito-occipital distance ("von Auge bis zum zwischen dem Occipitale und dem Atlas") and the lengths of the upper extremity, lower extremity, arm, forearm, thigh, and leg in prenatal life and at birth. The investigation is based upon measurements of 160 Japanese and 34 European fetuses ranging in age from the second fetal or lunar month to birth and from (approximately) 4 to 54 cm in crown-heel length. No individual case records are given, but the description of each dimension is accompanied by a field graph showing the relation of the measurement to the crown-heel length. Empirical formulae are given for the relations of the various dimensions to the crown-heel length in the fetal period and the curves of these formulae are shown on the field graphs. Material not sexed, but both series of specimens include equal numbers of males and females. The Japanese specimens were obtained from the district of Niigata. The exact source of the European material is not stated.

Arey ('23, '25). Discussion of the relation of crown-heel and crown-rump lengths to age in the fetal period with incidental consideration of the relation between these dimensions.

Arnovljević ('84). Measurements of the total body-length and the horizontal head circumference of 18 fresh specimens ranging from 12 to 54 cm in crown-heel length. Detailed description of each specimen given. Data summarized on the basis of age in lunar months. Material from Munich.

Belot ('13). Total body-lengths and horizontal chest circumferences of a series of living, fullterm, newborn children. The averages of these dimensions are given for birth and for each succeeding day to the eleventh thereafter. Separate averages given for males and females. Individual case records not published. Material from Paris.

Bondyreff ('02). Total body-lengths, occipito-frontal and bi-mastoid diameters, and horizontal head circumferences of 50 living, newborn children. Averages for each sex given in summary. Material from St. Petersburg. (Quoted from Gundobin '12.)

Bonnifay ('97). Data on the total body-length, horizontal head circumference, auriculo-vertex-auricular circumference, suboccipito-vertex-nasion circumference, bi-parietal diameter, and occipito-frontal diameter of infants of the first two weeks of postnatal life. In the available summary averages only are given, and there are no records of sex differences or of number of cases. Material from Lyon. (From the summary of Buschan-Stettin, Centralbl. f. Anthropol., Ethnol. u. Urges., 1898, 3:206-208.)

Brandt ('86). Total body-lengths and horizontal chest circumferences of 16 fresh specimens ranging from 13 to 54 cm in crown-heel length. Detailed description, including notation of sex, given of each specimen. Material from Munich.

Breslau ('62). Data on the horizontal head circumference obtained from the measurement of 576 premature and fullterm, living, newborn children ranging from 4 to 9.5 "eidgenossischen Pfunden" in body-weight. Average circumferences given separately for males and for females, for each half-pound range of body-weight. No individual case records published. Material from Zurich.

Budin and Ribemont ('79). Data on the total body-length, the occipito-mental, occipito-frontal, suboccipito-bregmatic, bi-parietal, bi-temporal, and bi-mastoid diameters, and the suboccipito-mental and suboccipito-bregmatic circumferences of 211 living, newborn children ranging from 41 to 56 cm in crown-heel length. Individual records published in detail, including notations of sex of infant, estimated duration of pregnancy, parity, and age of mother. Material from Paris.

***Burtscher ('77).** Measurements of the total body-length and the lengths of the upper extremity, lower extremity, arm, forearm, hand, thigh, leg, and foot of 17 fresh specimens ranging from 6.6 to 40.5 cm in crown-heel length. Individual cases recorded in detail, including notation of sex. Source of material not indicated in the original paper.

Cadre ('10). Total body-lengths and bi-parietal and occipito-mental diameters of 42 living, newborn children. Individual case records, including notation of sex, published. Material from Paris.

Calderini ('75). Total body-lengths, bi-parietal and bi-temporal diameters, and horizontal chest circumferences at the level of the nipples of 835 living, fullterm infants and prematures born in the last three months of pregnancy. Material sexed and records given in some detail. The study includes histograms illustrating the variability of the measurements. Material from the Obstetrical Institute of Parma.

Calkins ('21). A preliminary summary of the material presented in the following paper and in the present publication. A general statement of the character of growth of the external dimensions of the body in relation to the total body-length in the fetal period and the general type of mathematical expression thereof. No numerical data published.

***Calkins ('22).** Data on the total body-length, sitting-height, occipito-frontal, bi-parietal, suboccipito-bregmatic, suboccipito-frontal, and occipito-mental diameters and occipito-frontal, suboccipito-bregmatic, suboccipito-frontal, occipito-mental, and "large" head circumferences in the fetal period and at birth. Fixed specimens ranging from 23 to 544 mm in crown-heel length were studied. From 369 to 343 measurements were made of each dimension. Empirical formulae are given for the various dimensions in relation to total body-length. The tables include the average maximum and minimum observed values for each 5 cm interval of crown-heel length from 5 to 55 cm, inclusive, as well as the calculated values for these intervals and the average absolute and percentage differences between the observed and calculated values. There is included a field graph of each dimension showing the distribution of the individual observations and the curve of central tendency, as determined by the empirical formula. No individual case records of this series are given. Sex not given in the tables but indicated by special symbols on the field graphs.

A second series of observations gives the crown-heel lengths and head diameters and circumferences of 33 newborn, living infants delivered by Caesarean section. Individual case records, including notation of sex, are given for this series. Material from Minneapolis. The data given in this paper are included in the present study.

Calkins and Scammon ('25). Empirical formulae, computed by graphic methods, by the method of averages, and by the method of least squares, for the relations of 33 major external dimensions of the body to the crown-heel length, in the fetal period. This material is included in the present publication.

Carus ('54). Values for a series of 28 external dimensions of the newborn infant given in terms of moduli (modulus at birth being equal to one-third the length of the free vertebral column, or 6 mm). A figure, in profile, of a newborn drawn to these dimensions is included. The source of the observations and the number of individuals measured are not stated in the original text.

Caspar ('54). Measurements of 247 fullterm, newborn children (living and stillborn) and of 94 fetuses. The dimensions measured include total body-length, bi-acromial diameter, antero-posterior and transverse diameters of the thorax, breadth at hips, and antero-posterior, transverse, and diagonal diameters of the head. These figures are not complete for all cases. Individual cases published in detail, including notation of sex. Measurements recorded in Rhenish lines and inches.

Clarke (1786). Body-weights and horizontal head circumferences and auriculo-vertex-auricular circumferences of 40 living, newborn children. Individual measurements not published. Separate averages given for males and for females. Material from Dublin.

***Corrado ('99).** Extensive data on the total body-length, length of the foot, length of the hand, lengths of the upper and lower extremities, spread of the arms, horizontal (occipito-frontal) head circumference and occipito-frontal, occipito-mental, and bi-parietal diameters of the head as determined for a series of specimens ranging from 10.3 to 62.5 cm in crown-heel length. The fresh bodies of 250 specimens were used in the study, but all measurements were not made on all specimens. Individual records published in detail, including sex and many subsidiary data. Data summarized according to crown-heel length or body-weight. Material from Naples.

Daffner ('02). Data on the total body-length, horizontal head circumference, distance from vertex to nasion (?), breadth of face (bi-malar diameter ?), distance from nose to chin (?), width of mouth, nose length, nose breadth, length of ear, breadth of ear, neck circumference, transverse and antero-posterior diameters of the chest at the nipples, horizontal chest circumference at the nipples, distance between the nipples, distance from vertex to umbilicus, distance from umbilicus to sole, hand length, hand breadth, circumference of wrist, and length of the middle finger at birth. Average, and, in most instances, maximum and minimum values recorded. No individual case records published. The material is scattered through the publication, and it is impossible to ascertain in every instance the number of cases studied, but evidently 72 measurements were made for most of the minor dimensions and 130 for a number of the major ones. Apparently living children were measured. We have found no specific statement as to the source of the material, but the context suggests that the cases were from Munich.

Depaul ('79). Total body-lengths, occipito-frontal, occipito-mental, bi-parietal, and suboccipito-bregmatic diameters of 100 living, newborn children. Individual records published. Material sexed. Cases from Paris?

Fasbender ('78). Observations on the total body-length, bi-parietal, antero-posterior, and oblique diameters of the head, horizontal head circumference, antero-posterior diameter of the chest, horizontal chest circumference, inter-cristal diameter, interspinous diameter and external conjugate diameter of the pelvis, and the distance between the posterior superior iliac spines. The averages given for all of these dimensions, except those of the chest, are based upon 630 observations in all instances. The averages for the chest dimensions are apparently based upon 83 measurements. Subaverages are given for the material arranged according to sex, parity, and according to the age of the mother. The head dimensions are also averaged according to the size of the maternal head. No individual case records are published. Material from the Gebär-Abtheilung des Charité-Krankenhauses, Berlin.

***Faucon ('97).** Records of the total body-length, occipito-frontal, occipito-mental, suboccipito-frontal, bi-parietal, and bi-temporal diameters of the head, occipito-frontal, suboccipito-frontal, and suboccipito-bregmatic circumferences of the head, and distance from sole to umbilicus and from crown to umbilicus of 41 fresh specimens ranging from 4.6 to 43 cm in crown-heel length. Individual records published including sex and estimated age. Material from Paris.

Fehling ('75). Records of the total body-length and occipito-frontal head circumference of 252 premature and fullterm, newborn children taken in connection with a study of the dimensions of the frontal fontanelle. Most of these observations are made on living, fullterm infants but measurements of 48 prematures are included, and the majority of these were stillborn. Individual records published in detail, sex and parity included. There is also a table summarizing the relation between occipito-frontal circumference and crown-heel length in older fetuses and the newborn. Data from the Obstetric Clinic of Leipzig.

Frankenhäuser ('59). Transverse and sagittal diameters of the head as determined from measurements of 1,702 living, newborn infants. Separate averages are given for males and females. There is also a short table showing the relation of these dimensions in the infant to the size of the mother. A separate set of averages is also given for a series of 116 children delivered with forceps. No individual case records published. Data from Jena.

***Fridolin ('81).** Measurements of the total body-length and the lengths of the upper extremity, lower extremity, arm, forearm, hand, thigh, leg, and foot. The material consisted of fullterm and premature infants dying in the first year of postnatal life. There were 33 cases in which death occurred within one week after birth, and which approximate the newborn. Individual case records, including sex, given in detail. Data summarized on the basis of the total body-length. Hospital material, but the exact source not clear from the context.

***Friedenthal ('14).** Measurements of the total body-length, occipito-frontal diameter, bi-auricular diameter, vertical-auriculo-vertex distance, auriculo-mental distance, nasion-menton distance, distance from sternal notch to pubis, distance from menton to sternal notch, bi-acromial diameter, sterno-vertebral diameter at the level of the superior aperture of the thorax, antero-posterior diameter of the pelvis, intertrochanteric diameter, length of upper extremity, lengths of lower extremity, thigh, leg, foot, arm, forearm, and hand, and height of foot in the fetal period. Ten specimens, ranging from 50.82 to 500.5 mm in crown-heel length studied. One of these was a negro specimen, the remainder European. Individual case records published in detail, but sex not noted. Source of European material not stated.

Gönner ('84). Length of the foot as determined from a series of premature and fullterm, living, newborn infants. Material given by ranges in summarized form only, and number of cases not stated. Cases classified according to body-weight and sex. No body-lengths given. Material from Basel?

Grillenzoni ('68). Bi-parietal, mento-bregmatic, mento-frontal, cervico-bregmatic, and cervico-frontal diameters of the head, as determined from measurements of a large series of living, newborn children. A total of 555 individuals was studied, but the number of measurements taken of each dimension varies greatly. Data given in a summary that includes the number of observations for each dimension and the average values for males and females. Material from Milan?

Hamy ('80). Measurements of the height of the head and height of the nose as determined from a study of 10 fetuses. Individual figures given. Sex and body-length not noted.

Hasselwander ('03). Measurements of the total body-length, horizontal head (occipito-frontal) circumference, and foot length taken in connection with a study of the ossification of the skeleton of the foot. Ninety-two specimens, ranging from 14.5 to 59 cm in crown-heel length. Individual case records published, but in many instances certain of the measurements are missing. Sex not indicated. Material from Munich.

Hecker ('62). Data on the horizontal head circumference and the bi-parietal, occipito-frontal, and occipito-mental diameters of the head at birth. The available reviews of this investigation (Schröder '68 and Hoth '68) give average figures for males and females but no further particulars. Material from Munich.

***Heuser ('12).** Curves and average figures of the growth of the total body-length, occipito-frontal diameter, occipito-frontal circumference, head height, circumference of the chest at the level of the nipples, distance from umbilicus to rump, length of the lower extremity, and length of the foot in prenatal life.

Measurements made of 61 specimens, ranging from thirteen to forty-one weeks in estimated age. Averages given for each week of estimated age. Individual records limited to 8 of the younger specimens. Material not sexed. Specimens from the Marburg Frauenklinik.

Hoth ('68). Measurements of the bi-temporal, bi-parietal, occipito-frontal, and occipito-mental head diameters of 500 living, newborn children. In the only review of this study available to us there are given averages for these dimensions for each sex and for firstborn and later children. The maximum values of the series are also noted. Material from Marburg.

Kakuschkin ('12). Distance from crown to umbilicus and from umbilicus to sole as determined from measurements of 2,519 premature and fullterm, newborn children, ranging from 890 to 5,200 gm in body-weight. Cases averaged according to body-weight, sex, and mode of presentation at birth. No individual case records published. Material from St. Petersburg.

Kjölseth ('13). Total body-lengths and occipito-frontal, occipito-mental, bi-parietal, bi-temporal, and suboccipito-bregmatic diameters of the head and horizontal (occipito-frontal) head circumferences of a series of 534 living, newborn infants (premature, fullterm, and postmature). Average values given for all dimensions, and maximum and minimum values included for the horizontal head circumference. Subaverages given for cases arranged according to fetal age, parity, and age of mother. No individual case records published. Material from Christiania.

Klein ('96). Measurements of the intercristal, interspinous, intertrochanteric, and external conjugate diameters of 11 female and 6 male, living, newborn children. Individual measurements recorded but no body-lengths given. Material from Strasbourg.

Konikow ('94). Measurements of the intercristal, interspinous, intertrochanteric, and external conjugate diameters of 6 selected, newborn children. Individual records given. Material sexed but body-lengths not recorded. Cases from the Gynaecologic and Obstetric Clinic of Bern.

Körber ('84). Two series of observations on the horizontal head circumference and horizontal chest circumference of premature and fullterm, living infants. The first series consists of 4,556 observations from St. Petersburg. The figures are given in summary only, the absolute and percentage number of cases for each centimeter of head circumference from 31 to 37 cm, inclusive, being noted as well as the number of cases having circumferences above and below this range. Similar figures are given for each centimeter of chest circumference from 28 to 35 cm, inclusive, and for the values above and below this range. The second series consists of 7,810 cases from Moscow. They are summarized in the same manner, except that the numbers of cases for each centimeter interval of chest circumference are given from 30 to 37 cm, inclusive. Material not sexed and no body-lengths given.

Kultz ('69). Average bi-temporal, bi-parietal, occipito-frontal, and occipito-mental diameters in newborn infants. Separate averages given for males and females. The only available summary of this investigation, which is given in connection with an abstract of Hoth's study (*vide ante*), contains no further data.

***Lafaille ('93).** Measurements of the total body-length, distance from vertex to menton, distance from vertex to sternal notch, distance from vertex to gluteal folds, distance from vertex to groin, distance from sternal notch to pubis, distance from sternal notch to umbilicus, distance from sternal notch to gluteal folds, distance from umbilicus to perineum, distance from clavicle to anterior superior iliac spine, distance from clavicle to nipple, bi-mammary (nipple to nipple) distance, distance from seventh cervical vertebra to perineum, bi-acromial diameter, bi-humeral diameter, intertrochanteric diameter, distance from gluteal fold to sole, distance from inguinal fold to sole, distance from trochanter to sole, distance from perineum to sole, distance from anterior superior iliac spine to sole, length of thigh, length of leg and foot, height of foot, length of foot, length of upper extremity, distance from apex of axilla to tip of middle finger, distance from apex of axilla to olecranon, distance from olecranon to tip of middle finger, distance from acromion to fold of elbow, distance from acromion to olecranon, distance from apex of axilla to fold of elbow, distance from fold of elbow to base of middle finger, distance from olecranon to styloid process of radius, distance from olecranon to base of hand, hand length, length of middle finger, circumference of neck, occipito-mental diameter, occipito-frontal diameter, suboccipito-bregmatic diameter, bi-parietal diameter, bi-temporal diameter, bi-mastoid diameter, fronto-mental diameter, trachelo-bregmatic diameter, and spread of upper extremities. Study based upon measurements of 152 specimens ranging from 17.5 to 56 cm in crown-heel length. Most of the children were 45 cm or over in crown-heel length. Living material, with the exception of a few of the smaller individuals. Almost all measurements were taken on each specimen. Individual case records published in detail, including sex, parity, and presentation of child, duration of pregnancy, and age of mother. Material from Paris.

Le Damany ('10). Measurements of the total body-length, antero-posterior and transverse diameters of the head, intercristal diameter of the pelvis, height of pelvis, antero-posterior diameter of the pelvis at the anterior superior iliac spine and length of the lower extremity in two series of living, newborn children. The first series includes 336 white infants, presumably from Rennes, ranging from 405 to 539 mm in crown-heel length. No head dimensions are given for this series, and the height of the pelvis is recorded for 200 cases only. The remaining dimensions are given for all cases.

The second series consists of 52 newborn, Soudanese negro infants, measured on the third to eighth days, inclusive, and ranging from 425 to 611 mm in crown-heel length. The total body-lengths, head diameters, intercristal diameters, and extremity lengths are recorded for all these children.

Individual case records published in detail including a notation of tribe in connection with the negro material. Sex indicated. The study is supplemented by an extensive series of measurements of the dimensions of the skeletonized pelvis in the fetus and newborn.

***Legou ('03).** Records of the total body-length, occipito-frontal, occipito-mental, suboccipito-frontal, suboccipito-bregmatic, bi-temporal, bi-parietal, and submento-bregmatic diameters, and the occipito-frontal, suboccipito-frontal, and suboccipito-bregmatic circumferences of 114 fresh specimens ranging from 19.5

to 36 cm in crown-heel length. Individual records published, including sex. Cases averaged on the basis of estimated age. Material from Paris.

Liharžik ('58). Horizontal head circumference and horizontal chest circumference at birth as determined by measurements of 130 living, fullterm children between one and six days of age. Individual case records published. Sex noted, but no records of body-length given. One hundred cases from the Second Obstetric Clinic of Vienna and 30 from the Obstetric Clinic of Gratz.

Liharžik ('58, '62). Data on the total body-length, head circumference, chest circumference, distance from sole to pubis, length of head, transverse diameter of head, occipito-frontal (?) diameter of head, transverse and antero-posterior diameters of chest, length of sternum, distance from xiphoid process to umbilicus, distance from umbilicus to pubis, circumference of pelvis, antero-posterior (external conjugate?) diameter of pelvis, transverse (intercristal?) diameter of pelvis, length of arm, length of forearm, length of hand, length of thigh, and length of leg in the newborn. Averages given for males and females separately. No individual case records published. Number of observations not stated. Material from Vienna?

Lind ('76). Records of the total body-length and horizontal head circumference of 132 living, newborn, premature and fullterm children, collected in connection with a study of the dimensions of the frontal fontanelle. The specimens ranged from 40 to 55 cm in crown-heel length. Individual records published, including notation of sex. Data summarized on the basis of the body-length. Material from Berlin.

Linzenmeier ('14). Total body-lengths and horizontal chest circumferences before and after the first inspiration. The measurements were made on 40 living, newborn infants ranging from 47 to 54 cm in crown-heel length. Individual case records given. Material not sexed.

Lodoli ('87). Total body-length and hand length as determined from measurements of 60 premature and fullterm, newborn, living children ranging from 38 to 52.5 cm in crown-heel length. Individual case records, including sex and parity. Material from Vienna?

Lutz ('12). Body-lengths and horizontal head circumferences of 1,000 living, newborn children of the twenty-ninth to forty-fifth week of pregnancy. Material given in summary only, including the average values for males and females for each week. Number of cases for each week not stated. Data from Berlin.

***MacKeen ('19).** Measurements of the total body-length, sitting-height, sterno-pubic distance, sterno-umbilical distance, xiphi-sternal-umbilical distance, umbilico-pubic distance, distance from middle of inguinal ligament to costal arch (vertical), distance from twelfth rib to iliac crest, intercristal, interspinous, intertrochanteric, and external conjugate diameters of the pelvis, distance from the first lumbar vertebra to the lumbosacral articulation, vertical distance of the iliac crest above the level of the symphysis pubis, vertical distance of the twelfth rib above the level of the symphysis pubis, circumference at the level of the xiphisternal junction, circumference at the level of the tenth rib, circumference at the level of the umbilicus, circumference at the level of the iliac crests. The measurements were made on a series of 187 preserved fetuses and newborn infants ranging from 28 to 590 mm in total or crown-heel length. Average, maximum, and minimum values for each dimension given for each 5 cm of crown-heel length to 60 cm. Separate averages for males and females given for the pelvic dimensions. Curves of the growth of the various dimensions in relation to the crown-heel length are included in the study as well as histograms illustrating the absolute and relative changes in dimensions. Material from Minneapolis.

***Mall ('07).** Data on the total body-length, sitting-height, and length of the spinal column in the embryonic and fetal period. The study is based upon original observations and on measurements from illustrations to scale found in the literature. It includes measurements of 140 specimens of less than 20 mm, crown-rump length, 200 specimens between 20 and 100 mm, crown-rump length, and a large number (figure not given) of older specimens. Individual records not published. A table is given, which includes the median values for the length of the spine and the median crown-heel length for each 1 mm interval of crown-rump length from 2 to 20 mm, inclusive, and for each 5 mm interval of crown-rump length from 20 to 350 mm, inclusive. Empirical formulae are given for the expression of the relation between crown-rump length, spine length, and crown-heel length.

***Mall ('10).** Data on the total body-length, the sitting-height, and the *AR* length (the distance in a straight line from the level of the foramen magnum to the lowest point of the breech) in the embryonic and fetal periods. The crown-heel and crown-rump lengths are given for each week from three to thirty-nine, inclusive. These values were apparently obtained by graphic methods. The "probable deviation" (which apparently corresponds to the difference between the first and third quartile values) is also given for the crown-heel length for each week. There are no tabular data on the *AR* length. There are included field graphs and curves, apparently drawn by inspection, illustrating the relation between crown-heel, crown-rump, and *AR* length. Two sets of curves, also apparently drawn by inspection, illustrate the relation between these dimensions and age in prenatal life. Over 2,000 cases were included in the study and of these fully half were from Mall's collection. The remainder were obtained from the literature and by correspondence. Mall's material included a considerable number of negro fetuses.

Mandelstam ('80). Measurements of the total body-length, the occipito-frontal, bi-parietal, bi-temporal, occipito-mental, and suboccipito-bregmatic diameters, and occipito-frontal, occipito-mental, and suboccipito-bregmatic circumferences of 98 living, newborn infants ranging from 43 to 53 cm in crown-heel length. Individual case records including sex of child and parity. Material from the Second Obstetric Clinic of Prague.

Maurel ('06). Data on the horizontal circumference, antero-posterior and transverse diameters, thoracic index, and area of the thoracic section at the level of the xiphi-sternal junction at birth. The study is based upon measurements of 9 premature and fullterm, living, newborn children, ranging from 2,500 to 3,500 gm in body-weight. Material not sexed and individual case records published.

Averages given for cases arranged in groups according to 500 gm intervals of body-weight. Material from Paris.

Meeh ('94). Measurements on the cadaver of a single fullterm, male, newborn infant. The measurements taken were total body-length, occipito-frontal circumference, menton-bregma (?) circumference, occipito-frontal diameter, occipito-mental diameter, bi-mastoid diameter, bi-temporal diameter, intercristal diameter, interspinous diameter, intertrochanteric diameter, external conjugate diameter, circumference of the pelvis, length of the upper extremity, length of the arm, length of forearm, length of hand, wrist circumference, greatest circumference of the forearm, length of the lower extremity, length of thigh, length of leg, length of foot, height of foot, thigh circumference, calf circumference, circumference of the foot (through the heel and dorsum), circumference of the ankle, greatest antero-posterior diameter of the thorax, greatest transverse diameter of the thorax, circumference of the chest, and circumference of the abdomen.

Meigs ('43). Average occipito-frontal and bi-parietal diameters, horizontal head circumference, and "perpendicular or small circumference" at birth as determined from measurements of 150 living, fullterm, newborn infants. No individual case records published. No records of sex or body-length. Figures given in inches and lines. Material from Philadelphia.

***Michaelis ('06).** Measurements of the total body-length, sitting-height, trunk length, horizontal chest circumference, antero-posterior diameter of the thorax, bi-acromial diameter, circumference of the abdomen, lengths of the upper and lower extremities, occipito-frontal, occipito-mental, suboccipito-bregmatic, bi-temporal, and bi-parietal head diameters, and the occipito-frontal and horizontal head circumferences, in the fetal period. The material consisted of 90 fresh fetuses of the fourth to ninth (solar?) months, inclusive. Data in the form of tables, which give the average, maximum, and minimum measurements for each month of gestation. Material not sexed. Specimens from the Königliche Universitäts-Frauenklinik of Leipzig.

Nagahama ('03). Total body-lengths and circumferences of the head and thorax of 127 newborn, Japanese children. The available summary of this study gives the ranges of these dimensions only. Material sexed. (Quoted from the summary of Osawa, G., Jahresber. f. Anat., 1903, 3: 1008.)

Negri ('85). Observations on the bi-parietal diameter of the head and the length of the foot in 35 living, newborn infants. Individual records published in detail including sex, body-weight, and parity of mother. No total body-lengths given. Material summarized for each and both sexes, by averages for each 500 gm interval of body-weight from 2,000 to 3,500 gm, inclusive. Cases from the Obstetric Clinic of Novara.

***Noback ('22).** Data on the relation between crown-rump and crown-heel lengths in prenatal life and at birth. The study is based upon original observations and the data of Michaelis ('06), Weissenberg ('06), Mall ('10), MacKeen ('19), Taylor ('19), and Dunn ('21). Empirical formulae are given for the expression of the relation of crown-rump and crown-heel lengths, and this relation is also illustrated by a curve and field graph based upon the data listed above. A table giving the average absolute and average percentage deviations of the observed values of Mall, MacKeen, and Michaelis from the corresponding calculated values as obtained from the empirical formulae is included in the paper.

Pagliari ('95). Total body-lengths and horizontal head circumferences of 193 living, newborn children from Rome. Average figures (for each sex) only.

Pfannkuch ('72). Data on the total body-length, horizontal head circumference, distance from crown to umbilicus and distance from umbilicus to sole as determined from a study of 704 premature and fullterm, living, newborn children ranging from 1,500 to 4,000 gm in body-weight. Material published in summary only. The cases are averaged according to sex and parity for each 500 gm range of body-weight. Material from Marburg.

Popiel ('03). Total body-length, horizontal head circumference, occipito-frontal, occipito-mental, suboccipito-bregmatic, bi-parietal, and bi-temporal diameters of the head, bi-deltoid diameter and bi-deltoid circumference at birth as determined from measurements of 100 fullterm, living, newborn children. In the available summary there are given the average value for each measurement and its variability as determined by Stieda's formula. Sex differences are not noted. Material from Warsaw? (Quoted from the summary of Hoyer in the Jahresber. f. Anat. u. Entwickl., N. F., 9, Abt. 3, p. 1010.)

Quetelet ('70). Absolute and relative values of 71 external dimensions of the body at birth. Of these dimensions, 21 are of the head, 16 are of the neck and trunk, 19 are of the extremities, and the remainder involve more than one major division of the body. This work is so well known that it seems unnecessary to list these dimensions in more detail. The measurements were taken on cadavera of fullterm (?), newborn children. The averages only are published for each sex. The context indicates that the material was from the Maternitè of Brussels.

Ranke ('05). Data on the total body-length, trunk length (distance from the ischial tuberosities to the seventh cervical vertebra), length of the lower extremity (crown-heel length minus crown-rump length), horizontal (occipito-frontal) head circumference, sagittal head circumference (glabella to occiput), transverse head circumference (from one linea temporalis to the other), greatest head length and greatest head breadth at birth. The study is based on measurements of 11 male and 9 female, living, fullterm (?) infants. Average measurements are given for each sex. No individual case records published. Material from the Obstetric Clinic of Kiel.

Reiche ('16). Data on the total body-length, horizontal head circumference, and horizontal chest circumference in later fetal life and at birth. The material is incidental to a study of the growth of premature infants. Little tabular data but a considerable amount of material is presented in graphic form. Living material from Berlin.

***Reicher, M. ('23).** An extensive study of certain major external dimensions of a large series of human fetuses and newborn children. The fetal material consisted of a series of 366 specimens ranging from 41 to 438 mm in length and from nine to forty-two weeks in estimated age. These specimens were preserved in alcohol or formalin. Two hundred and twenty were from the Department of Embryology of the Carnegie Institute of Washington, 51 from the collection of the University of Chicago, 39 from the collection of the University of Michigan, and 56 from the collection of the University of Minnesota. The newborn material consisted of 81 living, fullterm infants from the Obstetric Department of the Child Jesus Hospital in Warsaw, Poland. The measurements taken were crown-heel length, crown-rump length with the body in the natural flexed position, crown-heel length with the body straightened, distance from the sternal notch to the symphysis pubis, length of the upper extremity (as determined from the sum of the lengths of the arm, forearm, and hand) and length of the inferior extremity (as represented by the lengths of the thigh and leg, without the foot).

Individual case records published in full, including notation of sex, but all measurements are not given for all specimens. Individual indices of the various dimensions in relation to the trunk length (distance from sternal notch to symphysis pubis) included. Material summarized according to estimated age in weeks and months. The average, maximum, and minimum measurements are included in these tables, as well as the average indices and the average absolute and average relative monthly increments in the various dimensions. The paper also contains numerous graphs of indices and of absolute and relative monthly increments. Publication is in Polish, but with English subcaptions for the tables and an extensive summary in English.

***Reicher, M. ('25).** Observations of the growth of the extremities in prenatal life based on measurements of 533 fetuses and 97 newborn infants. Material sexed. The measurements include lengths of the trunk, arm, forearm, hand, thigh, leg, and foot, and breadths of the hand and foot. Material summarized by estimated age in weeks, maximal, minimal, and average values, with the number of cases being given for each period. The various indices of these dimensions have been determined for each specimen and are published in detail. The material is in part from the collections in American universities (see Reicher '23, *ante*) and in part from the Institute of Anatomy and the Institute of Histology of the University of Warsaw and the Institute of Anatomy of Wilno. Publication is in Polish, but with French subscriptions for each table and an extensive summary in French.

***Retzius ('04).** An extremely detailed study of 32 external dimensions of the body as determined from measurements of 48 preserved specimens ranging from 9 to 170 mm in crown-rump length. The dimensions measured were crown-rump length, crown-heel length, trunk length, head length, head height, head breadth (bi-parietal diameter?), interauricular diameter, outer interocular distance, inner interocular distance, nose height, nose breadth, bi-malar diameter, maxillary height, face height, mouth breadth, bi-acromial diameter, intercristal diameter, distance from crown to umbilicus, distance from umbilicus to sole, distance from xiphi-sternal junction to umbilicus, distance from umbilicus to pubis, upper extremity length, arm length, forearm and hand length, hand length, hand breadth, lower extremity length, thigh length, leg length and foot height, foot length and foot height. The absolute and relative dimensions are listed in detail for each specimen and the individual records include notations of method of fixation and, in most cases, of sex. The study is supplemented with a series of measurements of the skeletal dimensions of another series of 39 fetuses. Material, in part at least, from Stockholm.

von Ritterschain ('70). Average total body-lengths, horizontal head circumferences, and horizontal chest circumferences of 11,432 premature and fullterm, living, newborn children. Material sexed. Cases from the Königliche Böhmischen Landes-Findelanstalt in Prague.

Rodes ('06). Body-lengths and antero-posterior and transverse diameters of the thorax at the level of the gladiolo-xiphoid articulation, of a series of 9 embryos, fetuses, and newborn children. The age of the specimens ranged from 5.5 (estimated) weeks (prenatal) to 5 days (postnatal). The crown-rump lengths of the six smaller and the crown-heel lengths of the three larger specimens are given. Individual records published, but sex not stated. All material studied had been fixed. "The specimens are mostly of the white race."

*__Roys ('19).__ Data on the total body-length, distance from sternal notch to pubis, distance from suprasternal notch to xiphi-sternal junction, distance between ninth pair of ribs, infrasternal angle, vertical distance from mid-clavicular point to ninth rib, vertical distance from mid-clavicular point to costal arch, vertical distance from mid-clavicular point to inguinal ligament, length of thoracic spine, sterno-vertebral angle, angle between twelfth rib and spine, antero-posterior diameter of thorax at superior aperture, at the axilla, at the nipples, and at the xiphi-sternal angle, transverse diameter of thorax at superior aperture, at the nipples, at the axilla, and at the xiphi-sternal junction, circumference of thorax at the axilla, at the nipples, and at the xiphi-sternal junction, and thoracic index at the xiphi-sternal junction. Sixty-one preserved specimens studied, ranging from 50 to 516 mm in crown-heel length. Not all measurements were made on all specimens. In particular the last 13 dimensions mentioned above were measured on 51 specimens only. Individual case records given in detail, including a notation of sex. Curves of the various dimensions plotted against the crown-heel length are included. Material from Minneapolis.

Scammon and Calkins ('25). A summary of a study of the relation between crown-heel and crown-rump lengths in the fetal period. General discussion with no detailed data.

Scammon and Rucker ('21). Data on the horizontal circumference and the antero-posterior and transverse diameters of the chest at the levels of the nipples and the tenth rib. Measurements made on 36 living, fullterm, newborn children fifteen minutes after birth and at various succeeding periods up to the twelfth day. Only average dimensions published. Material not sexed. Cases from the Minneapolis General Hospital.

Schadow ('54). Total body-length, head breadth (bi-temporal diameter), antero-posterior diameter of the trunk at the level of the tenth rib, transverse diameter of the trunk at the level of the tenth rib, distance from pubis to sternal notch, intercristal diameter, lengths of upper extremity, lower extremity, arm, forearm, hand and foot, and foot height in the newborn. Measurements evidently made on living, newborn children but number of cases not stated. Figures given in Rhenish feet and inches.

Schäffer ('92). Data on the total body-length and horizontal head circumference from the third to the tenth fetal months, inclusive. Figures given in the form of ranges for each fetal or lunar month. A large amount of numerical data on the dimensions of the skull is included. Material not sexed. Cases from Munich.

Schmid-Monnard ('92). Observations on the total body-length, horizontal head circumference, and horizontal chest circumference of the living, newborn infant. Average values only given for each sex. Number of cases not stated. Material from Frankfurt.

Schröder ('69). Records of the total (crown-heel) body-length, the horizontal head circumference, and the bi-temporal, bi-parietal, occipito-frontal, and occipito-mental diameters of the head of 383 living, fullterm, newborn infants. No individual case records published. Data averaged according to sex and parity. Material from Erlangen.

***Schultz ('19).** Measurements of the sitting-height, upper face height, nasal height, nasal breadth, interocular breadth, and nasal angles of 320 fetuses ranging from the tenth week to the tenth month, inclusive, in estimated age. Preserved material. Of the specimens 254 were whites, 58 American negroes, 4 Filipinos, 3 Indians, and 1 Japanese. Average, maximum, and minimum values given for each week from the tenth to twentieth weeks, inclusive, for two-week intervals from the twentieth to the close of the twenty-fourth week and for lunar months thereafter to birth. Age estimated from the sitting-height according to Mall ('10). Material not sexed. Separate averages given for whites and negroes. Separate tables giving indices based upon the above measurements.

***Schultz ('22, '23).** A summarized discussion of the changes in external body-form in prenatal life. The paper includes a consideration of sex differences, variability, asymmetry, the relation between the diameters and length of the trunk, the position of the nipples, position of the shoulders, relative length of the upper extremity and its several segments, relative length of the lower extremity and its several segments, relation between upper and lower extremity length, interrelations of head length, breadth, and height, growth of the face, changes in the eye, nose, and ear, and a number of minor points. Particular stress is laid on racial differences in prenatal material. No numerical data published, except illustrative material on the changes in relative dimensions and absolute increments. The paper is a preliminary report of the author's extensive study of the subject, which will be later published in detail. The study is based upon 623 selected white and negro specimens from the collection of the Carnegie Laboratory of Embryology.

***Schultz ('26).** A summary of a detailed study of fetal growth including the examination of a series of 623 human specimens, as well as a number of fetuses of apes and monkeys. Both white and negro fetuses are included in the fetal material but they are considered separately. The measurements were apparently made on preserved material. The measurements taken include horizontal head circumference, head length, head height, head breadth, total head height (vertex to chin), face breadth, interocular breadth, total face height, upper face height, nose height, nose breadth, sagittal and transverse diameters and horizontal chest circumference (at the level of the fourth ribs), distance from vertex to symphysis pubis, anterior trunk height, symphysion-acromion height, height of the shoulder over the sternal notch, bi-acromical breadth, bi-trochanteric breadth, position of the umbilicus, position of the nipples, lengths of upper extremity, lower extremity, upper arm, forearm, hand, and thumb, breadth of the hand, lengths of the lower extremity, thigh, leg, knee to sole and foot, foot breadth, and sitting-height. "Stature" (crown-heel length) was obtained by the distance from vertex to pubis, thigh length, and knee-sole length. The author prefers the sitting-height or "better still, the anterior trunk length" as a standard dimension. No individual measurements or means are recorded. A graph shows the trend of growth of stature, sitting-height, length of lower limb, anterior trunk length, and head length referred to age in weeks. The author makes use of a large series of indices in which all these are considered in more detail. The material is arranged with respect to age. There is a table of mean weekly coefficients of variation of 14 dimensions and another of the relative weekly increments (averaged by months) of 20 dimensions in the following sections of the present monograph. The author distrusts mathematical formulae for estimating fetal growth because of the high variability during fetal life. He bases his estimates of the ages of his specimens on Streeter's curve drawn by inspection.

Numerous observations on racial differences, differences between man and the primates, the fetus and the individual, as well as considerations of growth rates, compensating variations, asymmetries, and the like will be found in the original paper.

von Skalkowski ('90). Observations on the bi-temporal and bi-parietal head diameters of 200 living, newborn children. Individual records not published. The observations are averaged in groups on the bases of the corresponding maternal head dimensions. Material not sexed. Data from the Obstetric-Gynecologic Clinic of Chrobak in Vienna.

Solares ('81). Total body-lengths and occipito-frontal, occipito-mental, bi-parietal, and suboccipito-bregmatic diameters of 100 living, newborn children ranging from 40 to 57 cm in crown-heel length. Individual case records published, including notation of sex. Material from Paris.

Spiegelberg ('68). Data on the total body-length, the horizontal head circumference, and the bi-deltoid circumference as determined from measurements of 506 living, newborn children. Material summarized in groups on the basis of estimated age. Cases from the Gynecologic Clinic and the Polyclinic of the University of Breslau.

Spitzy ('03). Observations on the length of the foot, the foot circumference at the ball and at the instep, and the height of the longitudinal arch, as determined by measurements of 25 infants of the first year. Of these, 11 (4 prematures and 7 presumably fullterm children) were measured in the first two weeks of postnatal life. Individual records published. Sex and body-weight given, but not body-length. Material from the University Children's Clinic of Gratz.

Spondli ('57). Measurements of the total body-length and the bi-parietal, the occipito-frontal, and the occipito-mental diameters of 100 living, newborn, Zurich children. Individual case records, including sex, published.

Stratz ('09). Graphic representation of the external bodily proportions based on average dimensions of the newborn and measurements of one fetus of 25 and one of 4 cm crown-heel length. A table showing the relative head height at various body-lengths is included.

***Streeter ('20).** Data on the sitting-height, foot length, and head modulus (consisting of the sum of the greatest horizontal head circumference and the transverse bi-auricular arc divided by two) in prenatal life. Seven hundred and four specimens were measured. Of these 493 were of the white race, 126 negro, 26 were of other races, and 59 were not identified as to race or sex. The specimens ranged from 5.5 mm (flexed) to 376 mm in sitting-height. All were preserved, and a number of the larger ones were embalmed. Detailed individual records are published, which include the sex, race, grade of preservation, the estimated and, in many cases, the stated menstrual age, and some subsidiary data. Material summated according to age in weeks. Numerous field graphs and curves of the data are included.

Sutugin ('75). Total body-lengths, maximum and average bi-parietal diameters, and minimum bi-malar diameters of 180 premature and fullterm, living, newborn children. Individual case records not published and material not sexed. Figures summarized by intervals of crown-heel length. Material from St. Petersburg.

Tatewossoff ('99). Average body-length, trunk length, and interspinous, intercristal, intertrochanteric, and external conjugate diameters of the pelvis as determined by measurements of 32 living, fullterm, newborn children. Material sexed. Cases from St. Petersburg. (Quoted from the summary of Gundobin '12.)

Taylor ('19). Extensive data on the external bodily dimensions of 250 selected, fullterm, newborn children (125 of each sex). The measurements taken were total (crown-heel) body-length, head and neck height, distance from crown to umbilicus, sitting-height, upper extremity length, hand length, lower extremity length, foot length, intercristal diameter, intertrochanteric diameter, bi-deltoid diameter, horizontal chest circumference at the level of the nipples, occipito-frontal circumference, span of the upper extremities and trunk length. Average, maximum, and minimum values are given for each dimension for males and females. There are also included the standard deviations and coefficients of variability of the crown-heel length, the span of the upper extremities, the occipito-frontal circumference, and the chest circumference, for each sex. Coefficients of correlation are given for crown-heel length and span of upper extremities, crown-heel length, and occipito-frontal circumference and chest circumference for each sex. The individual case records are not given in the article as published, but these are on file in the Wistar Institute of Anatomy and Biology of Philadelphia. They include data on the length of gestation and race. Material from Minneapolis.

Turnbull ('62). Average bi-parietal and bi-mastoid diameters of the head in the fullterm, living, newborn infant as determined from measurements of 40 Australian children. No individual case records given. Material not sexed.

Van Pelt ('60). Measurements of the occipito-mental, occipito-frontal, and bi-parietal diameters of 646 living, newborn children. Material not sexed and individual case records not published. Averages given for each dimension as well as frequency tables showing the number of cases for each range of one-sixteenth of an inch in head diameter. Source of material not stated.

Weissenberg ('06). A series of measurements of 29 children (15 males and 14 females) dying at birth or within the first fortnight thereafter. The dimensions measured were the total body-length spread of the upper extremities, sitting-height, head and neck height, bi-acromial diameter, intercristal diameter, trunk length, horizontal head circumference, chest circumference at the nipples, and lengths of the upper and lower extremities, and of hand and foot. The results are given in summary including the average, maximum, and minimum values of each dimension for males and females. Material apparently from Berlin.

Weissenberg ('11). Data on the external dimensions of the body in prenatal life and at birth. The data on fetal dimensions include the total body-length, spread of the upper extremities, sitting-height, head and neck height, trunk length, length of upper extremity, length of lower extremity, bi-acromial diameter, intercristal diameter of pelvis, horizontal chest circumference, and horizontal head circumference of 13 specimens ranging in age from two to five and one-half fetal months. Russian, Jewish, and Polish material. Individual case records published, including notation of sex. No mention is made as to whether fixed or fresh specimens were studied.

The observations on the newborn are evidently those presented in Weissenberg's earlier study ('06), which is summarized above. The data are given in somewhat greater detail, the number of cases in various ranges of each dimension being included, and the height of the pelvis, as determined by subtracting the sitting-height and leg length from the total body-length, is added.

Weisz ('97). Determinations of the total body-length, the occipito-mental, suboccipito-bregmatic, occipito-frontal, bi-parietal, and bi-temporal diameters, and the occipito-frontal, occipito-mental, and suboccipito-bregmatic circumferences of the head of a series of fetuses of the fourth to tenth fetal months, inclusive, and of newborn children. Number of cases not stated, but probably extensive. Presumably both fresh dead and living specimens were used in the study. Average measurements given according to age in fetal months. Material not sexed and no individual records published. Material from Budapest.

Witzinger ('76). Horizontal head circumferences of 96 living, premature and fullterm, newborn infants. Individual cases reported in detail. Sex and parity noted. Material partially summarized on the basis of the total (crown-heel) length. Material from Bern.

PART III

SUMMARY OF FINDINGS ON THE MAJOR EXTERNAL DIMENSIONS OF THE BODY

I. Introductory Note

Under this heading are included four dimensions that involve more than one major division of the body. These are: the sitting-height (involving head and neck, trunk, and pelvis); the spine length (involving parts of the neck, trunk, and pelvis); the distance from crown to sternal notch (involving the head and neck, and a little of the upper part of the trunk); and the distance from the crown to the umbilicus (involving the head and neck, and the cranial part of the trunk). These dimensions were measured as straight lines parallel with the longitudinal axis of the body, except for the length of the spine, which was measured along the dorsal curvature of the body.

II. Consideration of Individual Dimensions*

1. Sitting-Height (Crown-Rump Length)

(Figure 13, Field Graph 1, Tables 10, 11, 168, and 180)

The crown-rump length or sitting-height was measured as a straight line parallel with the vertical axis of the body, extending from the crown to the level of the soft tissues over the ischial tuberosities. In making this measurement the head was held in an erect position, but was not extended, and the thighs were flexed at right angles to the long axis of the trunk. A slight but firm pressure was exerted against the soft tissues over the ischial tuberosities in each case. The experimental errors involved in determining this dimension have been discussed in detail in Part I, Section II, of this monograph.

Our experimental data indicate that there is an average increase of 1.6 per cent in this dimension with formalin injection, but this error becomes steadily less with subsequent preservation, dropping to 0.5 per cent at the end of six months. There is a small increase in the crown-rump length immediately after simple preservation in formalin without injection. Continued immersion results in a shrinkage which, in the case of our material, reduced the measurement in six months to an average of 0.4 per cent below the original figure.

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* The plan used in preparing the following summaries is described in Part I, Section IV (p. 54) of this monograph.

The results of our measurements of this dimension are shown in table 10 and in field graph 1. The calculated values computed from the several empirical formulae for this dimension show rather small deviations from the corresponding observed means except for the last three 5 cm intervals of body-length (from 40 to 55 cm crown-heel length). The mean absolute deviations are of the order of 3 mm, and the root mean square deviations range from 3.7 to 4.9 mm, and the the relative deviations fall between 1.4 and 2 per cent. In our opinion, the greater part of this error is due to the fact that the larger number of our specimens of the last three intervals of the distribution were relatively fresh material, which had been injected and were considerably enlarged by formalin artifacts.

TABLE 10

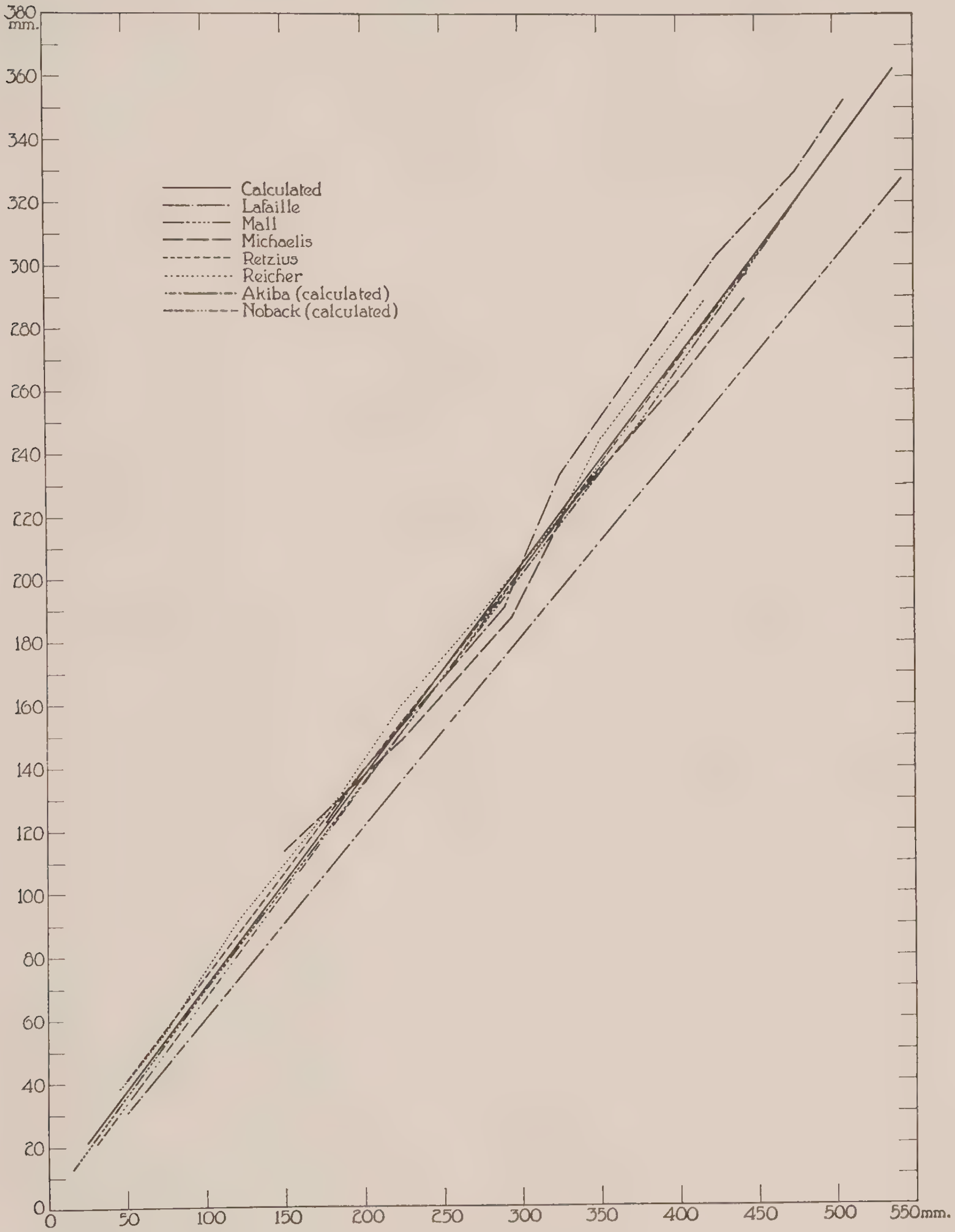
SITTING HEIGHT (CROWN RUMP)
.66 CH (MM.) + 5.0 MM. (356 CASES)

Crown Heel Length (mm.)		Sitting Height (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
		Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean	Max.	Min.	Mean (a)		mm.	Percent.				
23-50	37.2	41	21	31.4	29.6	-1.8	-5.7	17	5	38.0	—
50-100	75.4	71	39	57.0	54.8	-2.2	-3.9	29	10	71.0	118
100-150	124.8	104	73	88.9	87.4	-1.5	-1.7	44	15	104.0	46
150-200	173.2	138	103	119.6	119.3	-0.3	-0.3	27	20	137.0	32
200-250	224.5	167	135	151.8	153.2	+1.4	+0.9	49	25	170.0	24
250-300	273.1	218	167	183.9	185.2	+1.3	+0.7	46	30	203.0	19
300-350	324.5	237	198	218.4	219.2	+0.8	+0.4	34	35	236.0	16
350-400	368.8	269	234	247.0	248.4	+1.4	+0.6	30	40	269.0	14
400-450	423.2	319	264	287.6	284.3	-3.3	-1.1	29	45	302.0	12
450-500	471.4	342	295	328.5	316.1	-12.4	-3.8	24	50	335.0	11
500-544	523.6	388	337	358.1	350.6	-7.5	-2.1	27	55	368.0	10

Considering the importance attached to this measurement by anthropometrists, it is surprising that there are so few published observations on the relation of the sitting-height to the total body-length in the fetal period. Aside from a few incidental observations, the data on the subject seem to be confined to the work of Lafaille, Mall, Michaelis, Retzius, and Reicher. When taken as a whole, our observations are in very close agreement with those previously reported. Our findings are almost identical with those of Mall and of Reicher,

FIGURE 13

The Growth of the Sitting-Height (Crown-Rump Length) in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Sitting-height (mm).

but in the latter part of the distribution they are slightly above those of Retzius and of Michaelis, and distinctly below those of Lafaille.

There are also comparatively few published observations on the sitting-height in the newborn. The means of the chief series are shown in table 11. Several empirical formulae for the relation of sitting-height to crown-heel length have been developed by Mall, Noback, and Akiba. These are considered in the first part of the general discussion forming Part IX of this study.

TABLE 11

AVERAGE SITTING-HEIGHT (CROWN-RUMP LENGTH) AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE SITTING-HEIGHT (cm)
Bondyreff (males)	49.3	30.0
Bondyreff (females)	48.6	30.5
Quetelet (males)	50.0	34.0
Ranke (males)	49.9	33.0
Ranke (females)	48.6	32.0
Reicher (males)	49.3	33.3
Reicher (females)	49.4	33.0
Schultz (estimated from graph)	....	36.0
Taylor (males)	51.2	34.3
Taylor (females)	50.0	33.9
Weissenberg (males)	50.8	33.8
Weissenberg (females)	50.0	33.3
Present series (calculated)	50.2	33.6

2. Spine Length

(Field Graph 23, Table 12)

This measurement was made from the dorsum of the first cervical vertebra, in the median line, to the tip of the coccyx. The exact positions of these points were determined by needles pushed through the superficial tissues into the cartilaginous masses. The measurement was not taken vertically, but along the curve of the spine. The chief error of determination lies in inaccuracies in locating the exact upper margin of the arch of the first cervical vertebra. The spine length is increased 4.2 per cent by formalin injection. During subsequent preservation this increase rises to 5.6 per cent at one month, but thereafter declines to 4.3 per cent at six months.

Table 12 gives a summary of our findings for this dimension. The calculated values as determined by our empirical formulae for the 5 cm intervals or ranges of body-length, from 5 to 55 cm, inclusive, show mean absolute departures of the order of 2.5 to 3.5 mm, and the mean relative departures, as determined by the several criteria and methods of fitting employed, are all about 2 per cent. By far the largest deviations are found in the 50 to 55 cm interval of crown-heel length, and these are probably due mainly to artifacts.

TABLE 12

SPINE LENGTH (TOTAL)
.43 CH (MM.) + 4.0 MM. (296 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Length of Spine (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		CH Length cm	Value (mm.)	Per cent. increment
23-50	36.6	31.2	28.5	14	20.2	19.7	-0.5	-2.5	16	5	25.5	—
50-100	76.7	57.9	46	26.5	37.8	37.0	-0.8	-2.1	29	10	47.0	82
100-150	123.3	87.9	69	44	56.0	57.0	+1.0	+1.8	40	15	68.5	46
150-200	171.7	119.1	93	68	78.2	77.8	-0.4	-0.5	21	20	90.0	31
200-250	223.7	151.1	111	88	98.5	100.2	+1.7	+1.7	40	25	111.5	24
250-300	274.3	183.7	137	103	118.9	121.9	+3.0	+2.5	35	30	133.0	18
300-350	326.6	220.5	162	129	144.6	144.4	-0.2	-0.1	31	35	154.5	15
350-400	369.1	248.1	175	143	160.2	162.7	+2.5	+1.6	26	40	176.0	14
400-450	421.0	287.3	217	169	191.7	185.0	-6.7	-3.5	20	45	197.5	12
450-500	474.5	321.9	226	193	211.4	208.0	-3.4	-1.6	17	50	219.0	11
500-544	524.6	360.8	266	220	242.4	229.6	-12.8	-5.3	21	55	240.5	9

We found no previously published observations of this measurement of the spine in the fetus or newborn. The calculated natal value for this dimension at 50.2 cm crown-heel length, as determined by our graphic formula, is 22.9 cm.

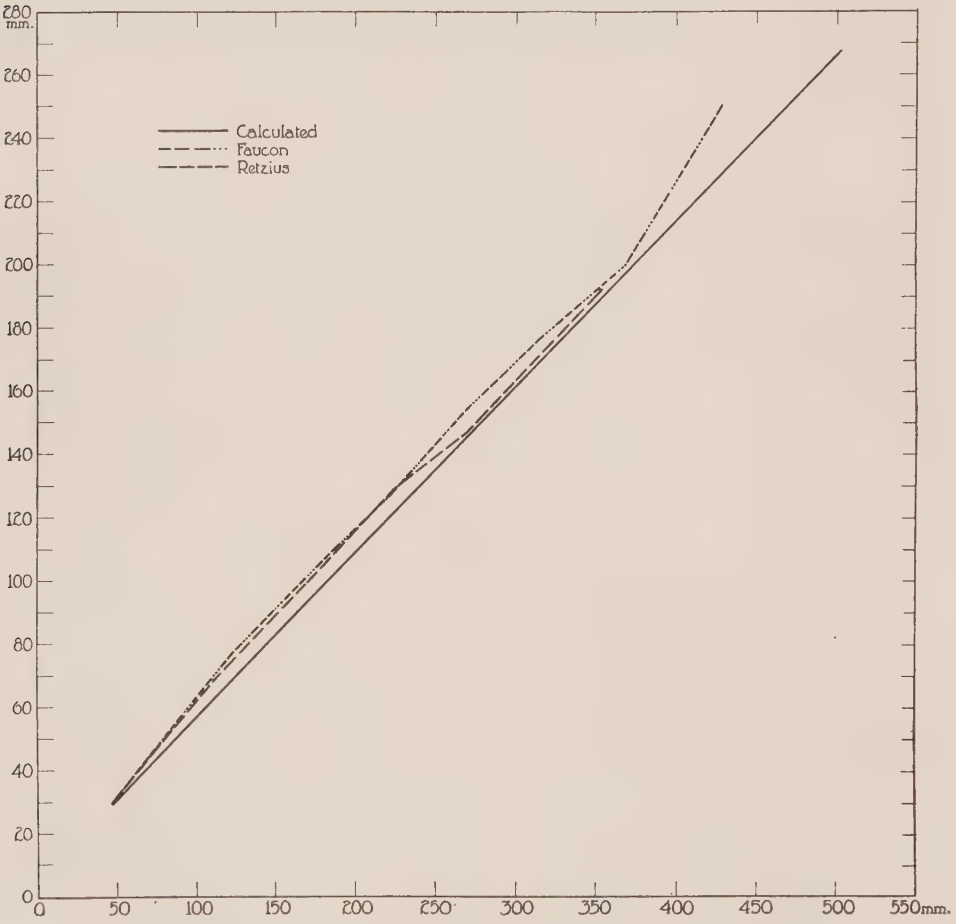
3. Distance from Crown to Umbilicus

(Figure 14, Field Graph 24, Tables 13, 14, and 168)

This measurement was defined as a vertical line parallel with the long axis of the body, extending from the vertex of the crown to the level of the middle of the area of attachment of the umbilical cord. The dimension was measured with the head in an erect position, but not extended. The measurement is increased about 2.5 per cent by injection, and this artifact is retained or even a little increased with subsequent preservation in formalin. It is probable that the dimension is slightly reduced by birth moulding.

FIGURE 14

The Growth of the Distance from Crown to Umbilicus in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Distance from crown to umbilicus (mm).

Table 13 summarizes our findings on the growth of the dimension with respect to body-length in the fetal period. Considering the experimental errors involved in making this measurement, the fits between the observed and calculated values for the 5 cm interval averages are quite close. The mean absolute deviations, as computed with various criteria, are all less than 2 mm, and the root mean square deviations range between 2.2 and 2.6 mm. The mean relative deviations are of the order of 1.0 to 1.5 per cent.

TABLE 13

CROWN TO UMBILICUS (VERTICAL)
.52CH(MM.)+5.5MM. (234 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Crown to Umbilicus (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	35.1	30.3	32	15.5	23.8	23.8	±0.0	±0.0	13	5	31.5	—
50-100	76.6	57.8	59	30	46.4	45.3	-1.1	-2.4	22	10	57.5	83
100-150	123.3	88.0	83	60	71.5	69.6	-1.9	-2.7	27	15	83.5	45
150-200	173.2	119.4	110	79	97.2	95.6	-1.6	-1.6	20	20	109.5	31
200-250	226.7	153.4	141	111	123.8	123.4	-0.4	-0.3	27	25	135.5	24
250-300	272.9	183.8	176	135	146.1	147.4	+1.3	+0.9	21	30	161.5	19
300-350	326.8	220.0	192	152	173.9	175.4	+1.5	+0.9	28	35	187.5	16
350-400	370.5	249.9	218	176	198.1	198.2	+0.1	+0.1	23	40	213.5	14
400-450	422.6	288.2	250	190	221.4	225.3	+3.9	+1.8	19	45	239.5	12
450-500	474.3	322.2	274	243	255.9	252.1	-3.8	-1.5	18	50	265.5	11
500-544	525.5	362.8	309	268	282.5	278.8	-3.7	-1.3	16	55	291.5	10

Both Faucon and Retzius have studied the growth of this dimension in the fetal period. Their averages run somewhat above our calculated values throughout. This dimension has been studied in the newborn by several observers. These average natal values are given in table 14.

TABLE 14

AVERAGE DISTANCE FROM CROWN TO UMBILICUS AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE DISTANCE FROM CROWN TO UMBILICUS (cm)
Daffner	50.6	27.6
Kakuschkin (males)	50.5	26.9
Kakuschkin (females)	50.1	26.6
Quetelet (males)	50.0	27.5
Quetelet (females)	49.4	27.2
Taylor (males)	51.2	26.6
Taylor (females)	50.0	25.8
Present series (calculated)	50.2	26.65

4. Distance from Crown to Sternal Notch

(Figure 15, Field Graph 25, Tables 15, 16, and 168)

This dimension represents the distance from the vertex to the suprasternal or sternal notch, measured in a plane parallel with the vertical axis of the body in the median line. This measurement was made with the head in an erect position, but not extended. The dimension is affected by a number of errors, including formalin artifacts, posture, and birth moulding. Formalin injection seems to cause a shrinkage of 4.1 per cent in this dimension. There is little change with subsequent immersion in formalin, the correction figure after six months being +4.7 per cent.

TABLE 15

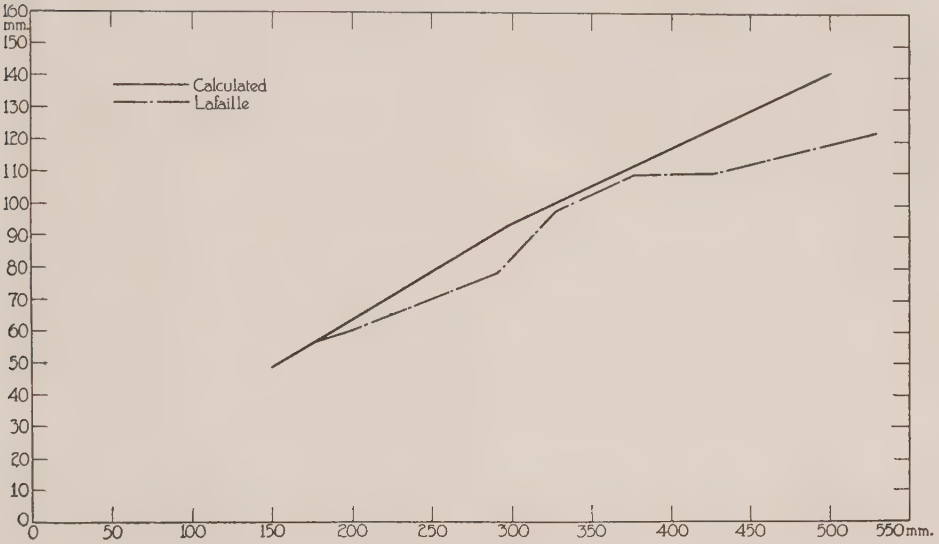
CROWN TO SUPRASTERNAL NOTCH (VERTICAL)
5 TO 30 CM. CH: .3 CH (MM.) + 4.0 MM.
30 TO 55 CM. CH: .24 CH (MM.) + 22.0 MM.
(284 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Crown to Suprasternal Notch (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.				
23-50	36.0	30.9	18	9	14.2	14.3	+0.1	+7.0	14	5	19.0	—
50-100	76.9	57.9	35	17	27.8	27.5	-0.3	-1.1	27	10	34.0	79
100-150	123.4	87.8	50	32	41.7	41.5	-0.2	-0.5	39	15	49.0	44
150-200	164.6	120.5	63	47	55.9	53.9	-2.0	-3.6	17	20	64.0	31
200-250	224.2	150.9	81	62	70.8	72.2	+1.4	+1.9	39	25	79.0	23
250-300	274.3	183.7	97	76	85.1	86.3	+1.2	+1.4	35	30	94.0	19
300-350	326.9	220.5	109	83	94.9	100.4	+6.5	+6.5	31	35	106.0	13
350-400	368.4	248.0	118	96	106.4	110.4	+4.0	+3.8	24	40	118.0	11
400-450	421.3	287.4	125	106	116.4	122.1	+6.3	+5.9	20	45	130.0	10
450-500	474.5	321.9	140	116	129.2	137.9	+8.7	+6.7	17	50	142.0	9
500-544	524.7	360.8	148	132	139.7	147.9	+8.2	+5.8	21	55	154.0	8

Table 15 summarizes our observations for this dimension. As in the case of most measurements in the median line of the anterior surface of the body, the curve of the distance from crown to sternal notch has been phased at 30 cm crown-heel length, the segments being drawn as straight lines of different slopes. The deviations of the calculated from the observed values for the 5 cm intervals of progression range from 2.5 to nearly 4 mm and from about 2.5 to 3.5 per cent, depending on the method of fitting and the test of fit employed. The major parts of these deviations lie in the upper segment of the progression and are due to the correction for formalin artifacts, which, as has been pointed out above, amounts to about 4.5 per cent.

FIGURE 15

THE GROWTH OF THE DISTANCE FROM THE CROWN TO STERNAL NOTCH IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Distance from the crown to sternal notch (mm).

Apparently the only published observations upon this dimension in the fetal period are those of Lafaille. When his findings are plotted in graphic form they present an extremely irregular curve with values distinctly below those found in this study. It is quite

TABLE 16

AVERAGE DISTANCE FROM CROWN TO STERNAL NOTCH AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE DISTANCE FROM CROWN TO STERNAL NOTCH (cm)
Quetelet (males)	50.0	14.0
Quetelet (females)	49.4	13.9
Taylor (males)	51.2	12.9
Taylor (females)	50.0	11.5
Present series (calculated)	50.2	14.2

possible that Lafaille's lower values are due to the fact that his measurements were made on living children, and it is extremely difficult to determine this dimension accurately in the living.

The only published observations we have found on this dimension in the newborn are those of Taylor and of Quetelet. Our calculated natal value is in close agreement with Quetelet's findings.

III. Résumé and Discussion of Findings on the Major External Dimensions of the Body

The empirical formulae, as developed by graphic methods, for the four major external dimensions of the body considered in this section, are in three instances expressions for simple straight lines and are characterized by positive *b* constants. The empirical formulae for the fourth measurement, the distance from the crown to the sternal notch, represent two straight lines phased at 30 cm crown-heel length. The *b* constants for both segments of this progression are positive.

TABLE 17

Calculated Values of the Major External Dimensions of the Body at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Formulae		Calculated values (mm.) at crown-heel lengths of:									
	a	b	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Crown-heel length	1.0	—	50.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
Crown-rump length (sitting height)	.66	+ 5.0	38.0	71.0	104.0	137.0	170.0	203.0	236.0	269.0	302.0	335.0
Spine length	.43	+ 4.0	25.5	47.0	68.5	90.0	111.5	133.0	154.5	176.0	197.5	219.0
Crown to umbilicus	.52	+ 5.5	31.5	57.5	83.5	109.5	135.5	161.5	187.5	213.5	239.5	265.5
Crown to suprasternal notch	.3 .24	+ 4.0 +22.0	19.0	34.0	49.0	64.0	79.0	94.0	106.0	118.0	130.0	142.0

Table 17 summarizes the computed values of these dimensions at each 5 cm interval of crown-heel length from 5 to 50 cm, inclusive, and the curves in figure 16 represent them graphically. The absolute and percentage increments of the dimensions of this group for each 5 cm interval of crown-heel length from 5 to 55 cm, inclusive, are included in the special tables for the individual measurements, (tables 10, 12, 13, and 15). Table 18 gives the computed values of these dimensions at the close of each month of the fetal period, and figure 17 represents their computed growth with respect to time.

TABLE 18

Calculated Values of the Major External Dimensions of the Body at the Close of Each Month of the Fetal Period

Dimension	Formulae		Calculated values (mm.) at:							
	a	b	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Crown-heel length	1.00	± 0.0	70.8	155.4	227.9	292.0	350.5	404.3	454.7	502.0
Crown-rump length (sitting height)	.66	+ 5.0	51.7	107.6	155.4	197.7	236.3	271.8	305.1	336.3
Spine length	.455	+ 1.0	33.2	71.7	104.7	133.9	160.5	185.0	207.9	229.4
Crown to umbilicus	.52	+ 5.5	42.3	86.3	124.0	157.3	187.8	215.7	241.9	266.5
Crown to suprasternal notch	.3 .24	+ 4.0 +22.0	25.2	50.6	72.4	91.6	106.1	119.0	131.1	142.5

The absolute and percentage increments of each of these dimensions in each month of the fetal period are summarized in tables 19 and 20. In the fourth month the fetus makes a computed increment of 84.6 mm in total or crown-heel length, while the corresponding gains of the other major dimensions range from 55.8 mm for the crown-rump length to 25.4 mm for the distance from the crown to

TABLE 19

Calculated Absolute Increments of the Major External Dimensions of the Body in Each Month of the Fetal Period

Dimension	Absolute increments (mm.) in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Crown-heel length	84.6	72.5	64.1	58.5	53.8	50.4	47.3
Crown-rump length (sitting height)	55.8	47.9	42.3	38.6	35.5	33.3	31.2
Spine length	38.5	33.0	29.2	26.6	24.5	22.9	21.5
Crown to umbilicus	44.0	37.7	33.3	30.4	28.0	26.2	24.6
Crown to suprasternal notch	25.4	21.8	19.2	14.5	12.9	12.1	11.4

TABLE 20

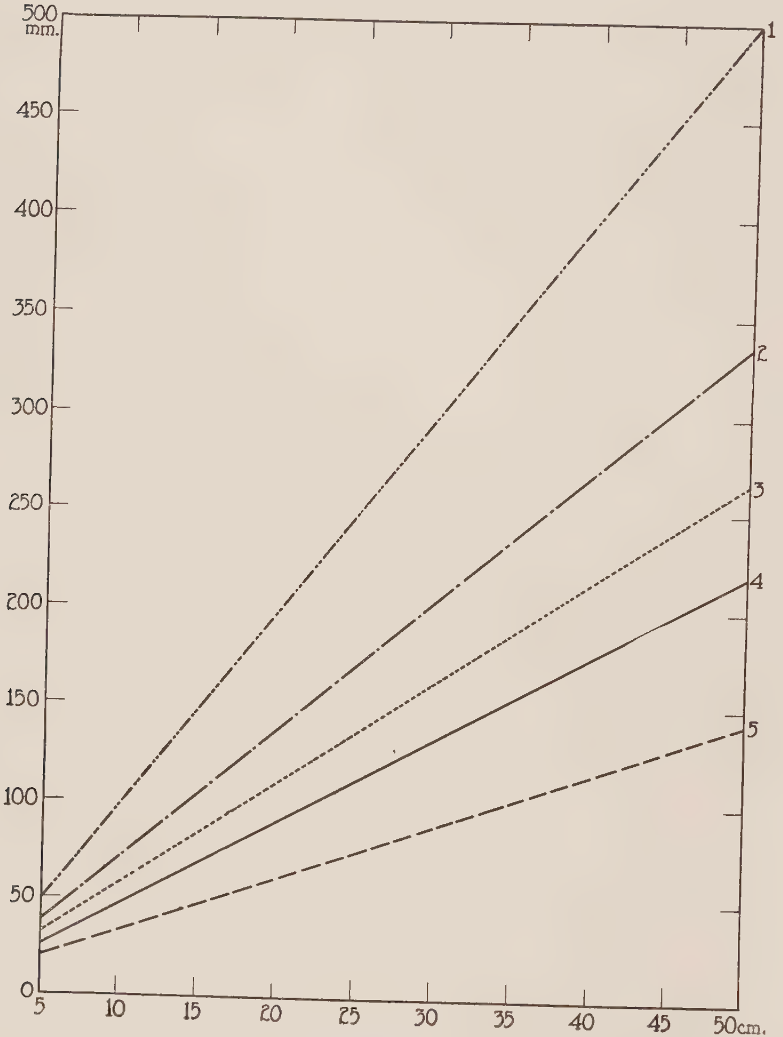
Calculated Percentage Increments of the Major External Dimensions of the Body in Each Month of the Fetal Period

Dimension	Percentage increments in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Crown-heel length	119.5	46.7	28.1	20.0	15.3	12.5	10.4
Crown-rump length (sitting height)	107.9	44.5	27.2	19.5	15.0	12.3	10.2
Spine length	116.0	46.0	27.9	19.9	15.3	12.4	10.3
Crown to umbilicus	104.0	43.7	26.9	19.3	14.9	12.1	10.2
Crown to suprasternal notch	100.8	43.1	26.5	15.8	12.2	10.2	8.7

the sternal notch. These absolute increments decline rapidly. In the eighth month the crown-heel length increases 53.8 mm and the increments in the other dimensions of the group range from 35.5 to

FIGURE 16

The Growth of the Major Dimensions of the Body (as Determined by Empirical Formulae) in the Fetal Period with Respect to Growth in Crown-Heel Length



Abscissa: Crown-heel length (cm). Ordinates: Major external dimensions of the body (mm).

1. Standing-height (crown-heel length)
2. Sitting-height (crown-rump length)
3. Distance from crown to umbilicus
4. Spine length
5. Distance from crown to sternal notch

12.9 mm. The absolute gains in the tenth fetal month are approximately half as great as in the fourth month, ranging from 47.3 mm for the crown-heel length, to 11.4 mm for the distance from the crown to the sternal notch.

TABLE 21

Per Cent of Natal Value Attained by Each Major External Dimension of the Body at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Percentage of natal value at crown-heel lengths of:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Crown-heel length	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Crown-rump length (sitting height)	11.3	21.2	31.0	40.9	50.7	60.6	70.4	80.3	90.2	100.0
Spine length	11.7	21.5	31.3	41.1	50.9	60.7	70.5	80.4	90.2	100.0
Crown to umbilicus	11.7	21.6	31.5	41.2	51.0	60.8	70.6	80.4	90.2	100.0
Crown to suprasternal notch	13.4	23.9	34.5	45.1	55.6	66.2	74.6	83.1	91.5	100.0

Each of these dimensions more than doubles its size in the fourth month, the percentage increments ranging from 119.5 for the crown-heel length, to 100.8 for the distance from the crown to the sternal notch. The increments drop rapidly, and in the seventh month the crown-heel length makes an increase of 20.0 per cent, and the other dimensions of the group increase from 19.9 per cent for the spine length, to 15.8 per cent for the distance from the crown to the sternal notch. In the tenth month all the dimensions make a gain of a little over 10 per cent, except the distance from the crown to the sternal notch which increases but 8.7 per cent.

TABLE 22

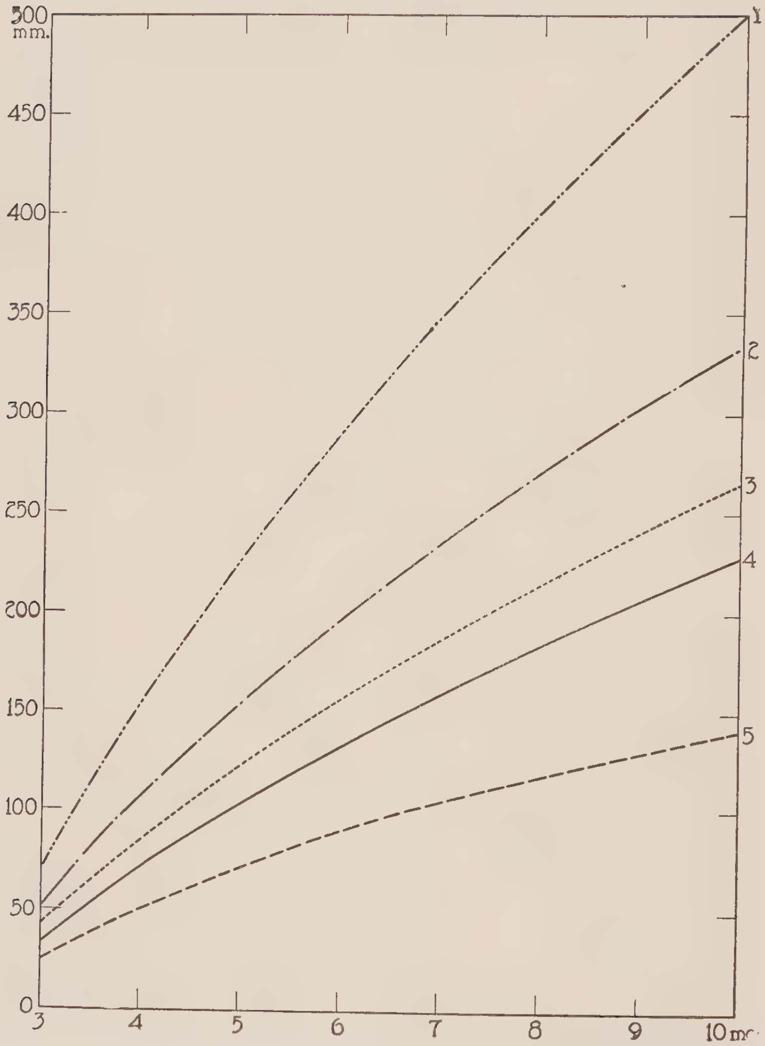
Per Cent of Natal Value Attained by Each Major External Dimension of the Body at the Close of Each Month of the Fetal Period

Dimension	Percentage of natal value at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Crown-heel length	14.1	31.0	45.4	58.2	69.8	80.5	90.6	100.0
Crown-rump length (sitting height)	15.4	32.0	46.2	58.8	70.3	80.8	90.7	100.0
Spine length	14.5	31.3	45.6	58.4	70.0	80.6	90.6	100.0
Crown to umbilicus	15.9	32.4	46.5	59.0	70.5	80.9	90.8	100.0
Crown to suprasternal notch	17.7	35.5	50.8	64.3	74.5	83.5	92.0	100.0

Table 21 shows the percentage of the natal value (computed as at 50 cm total body-length) attained by each dimension at the close of each 5 cm interval of crown-heel length. At 5 cm crown-heel length these dimensions average a little over one-tenth their natal size, the range being from 11.3 per cent for the crown-rump length,

FIGURE 17

The Growth of the Major External Dimensions of the Body (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Major external dimensions of the body (mm).

1. Standing-height (crown-heel length)
2. Sitting-height (crown-rump length)
3. Distance from crown to umbilicus
4. Spine length
5. Distance from crown to sternal notch

to 13.4 per cent for the distance from the crown to the sternal notch. At 25 cm crown-heel length the dimensions have attained a little over one-half of their natal size, the range being from 50.7 per cent for the crown-rump length, to 55.6 per cent for the distance from the crown to the sternal notch. At 45 cm crown-heel length the total body-length is of course 90 per cent of its value at 50 cm and the other dimensions of this group have attained from 90.2 to 91.5 per cent of their values at 50 cm.

TABLE 23

Relative Size of the Major External Dimensions of the Body (Computed as Per Cents of the Crown-Heel Length) at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Per cent. of total (crown-heel) length at:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Crown-rump length (sitting height)	76.0	71.0	69.3	68.5	68.0	67.6	67.4	67.2	67.1	67.0
Spine length	51.0	47.0	45.7	45.0	44.6	44.3	44.1	44.0	43.9	43.8
Crown to umbilicus	63.0	57.5	55.7	54.8	54.2	53.8	53.6	53.4	53.2	53.1
Crown to suprasternal notch	38.0	34.0	32.7	32.0	31.6	31.3	30.3	29.5	28.9	28.4

The computed percentages of natal value attained by each dimension at the close of each month in the fetal period are shown in table 22. At three fetal months the crown-heel length is 14.1 per cent of its natal value, while the corresponding figures for the other dimensions range from 14.5 per cent for the spine length, to 17.7 per cent for the distance from the crown to the sternal notch. At six months all of the dimensions, with the exception of the distance from the

TABLE 24

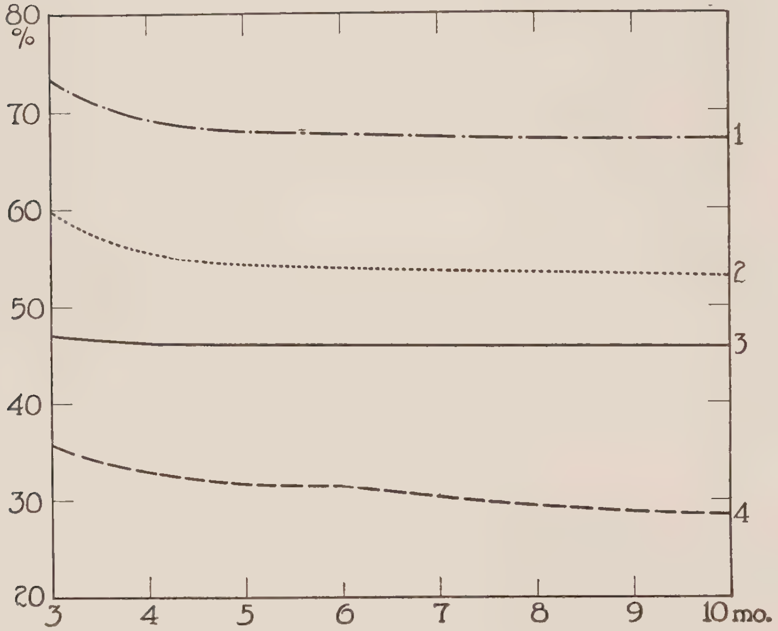
Relative Size of the Major External Dimensions of the Body (Computed as Per Cents of the Crown-Heel Length) at the Close of Each Month of the Fetal Period

Dimension	Per cent. of total (crown-heel) length at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Crown-heel length	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Crown-rump length (sitting height)	73.0	69.2	68.2	67.7	67.4	67.2	67.1	67.0
Spine length	46.9	46.1	45.9	45.9	45.8	45.8	45.7	45.7
Crown to umbilicus	59.7	55.5	54.4	53.9	53.6	53.4	53.2	53.1
Crown to suprasternal notch	35.6	32.6	31.8	31.4	30.3	29.4	28.8	28.4

crown to the sternal notch, have attained nearly 60 per cent of their prenatal growth, and the last dimension is 64.3 per cent of its natal size. At nine months all of these dimensions are about nine-tenths of their natal size, the range being from 90.6 per cent for the spine length and the crown-rump length, to 92.0 per cent for the distance from the crown to the sternal notch.

FIGURE 18

The Changes in the Relative Size of the Major External Dimensions of the Body in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the major external dimensions of the body expressed as per cents of the crown-heel length.

1. Sitting-height (crown-rump length)
2. Distance from crown to umbilicus
3. Spine length
4. Distance from crown to sternal notch

The calculated relative size of the various dimensions at each 5 cm interval of crown-heel length, and at each month of the fetal period, are shown in tables 23 and 24. Figure 18 shows these changes with respect to time in the fetal period in the form of curves.

The calculated crown-rump length or sitting-height forms approximately three-fourths (76.0 per cent) of the crown-heel length at 5 cm and declines to about two-thirds (67.0 per cent) at birth. At three fetal months it is 73.0 per cent, at six months, 67.7 per cent, and at birth, 67.0 per cent of the total body-length. These figures agree fairly well with those of Schultz ('26), who, however, computes the total or crown-heel length as a percentage of the sitting-height. Reicher ('23) also finds a relative decrease in the sitting-height.

The relative length of the spine undergoes less change. It is equivalent to 51.0 per cent of the total body-length at 5 cm crown-heel length and to 43.8 per cent at 50 cm. The computed relative value at three fetal months is 46.9 per cent and it decreases very slightly to 45.7 per cent at birth.

The computed relative length of the distance from the crown to the umbilicus is 63.0 per cent of the total body-length at 5 cm and drops approximately 10 per cent to 53.1 at birth. It forms 59.7 per cent of the body-length at three fetal months and but 53.1 per cent at birth. Thus the navel is ascending in position during the fetal period although it still lies below the midpoint of the body in the newborn. This observation agrees with the findings of early workers in legal medicine, who used the position of the umbilicus as a diagnostic sign in determining the maturity of the newborn infant.

The calculated distance from the crown to the sternal notch is equivalent to 38 per cent of the total length of the body at 5 cm crown-heel length but declines to 28.4 per cent at 50 cm. With respect to time, it is equal to 35.6 per cent of the body-length at three fetal months, 31.4 per cent at six months, and 28.4 per cent at ten months or birth.

PART IV

SUMMARY OF FINDINGS ON THE EXTERNAL DIMENSIONS OF THE HEAD AND NECK

I. Introductory Note

The study of the growth of the head and neck in the fetal period was based upon quantitative data on 22 dimensions of this part of the body. Eight of these dimensions were either complete circumferences (occipito-frontal, occipito-mental, suboccipito-bregmatic, suboccipito-frontal, large or menton-lambda, and neck circumferences) or perimetric measurements of major arcs of the head (auriculo-vertex-auricular and suboccipito-vertex-nasion circumferences). The remainder were diameters or distances, the latter term being used in distinction to the former to designate chords of relatively small arcs of head circumference. Twelve dimensions involved only the neural region of the head, 3 only the facial or visceral region, 6 both the neural and facial regions, and one (the neck circumference) included only the cervical region. Thus our information on the neural region of the head is much more complete than that on the facial region. Four of the dimensions were in the transverse plane of the body, 3 in the vertical or cranio-caudal plane, 4 in the antero-posterior plane and the remainder were oblique diameters or circumferences of measured partial arcs of the head.

II. Consideration of Individual Dimensions*

5. Occipito-Frontal (Horizontal) Circumference of the Head

(Figure 19, Field Graph 2, Tables 25, 26, and 169)

This measurement represents the largest circumference of the head, passing through the glabella and the inion. The mechanical errors in its determination seem to be quite small. Injection increases this circumference nearly 4 per cent. Subsequent immersion in formalin produces a further slight increase, and at the end of six months' preservation a subtraction of 4.3 per cent from the observed value is required to give the value for fresh material. Preservation in 10 per cent formalin solution, without injection, caused an increase of from 1 to 2 per cent in this dimension in the small series of cases studied.

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* The plan used in preparing the following summaries is described in Part I, Section IV (p. 54) of this monograph.

Birth moulding produces a marked decrease in this dimension, as is shown by a comparison of the measurements of unmoulded heads with those of fresh and preserved specimens. The circumference values for these types of material at 50 cm crown-heel length are as follows: fresh specimens, 32.25 cm; injected and preserved specimens, 33.70 cm; and living "unmoulded" heads, 35.00 cm. From these figures it appears that moulding causes a decrease of 2.5 to 3.0 cm in the circumference.

TABLE 25

Occipito-Frontal Circumference of Head (Glabella Inion)
.675 C.H.(mm) + 13.0 mm. (367 cases)

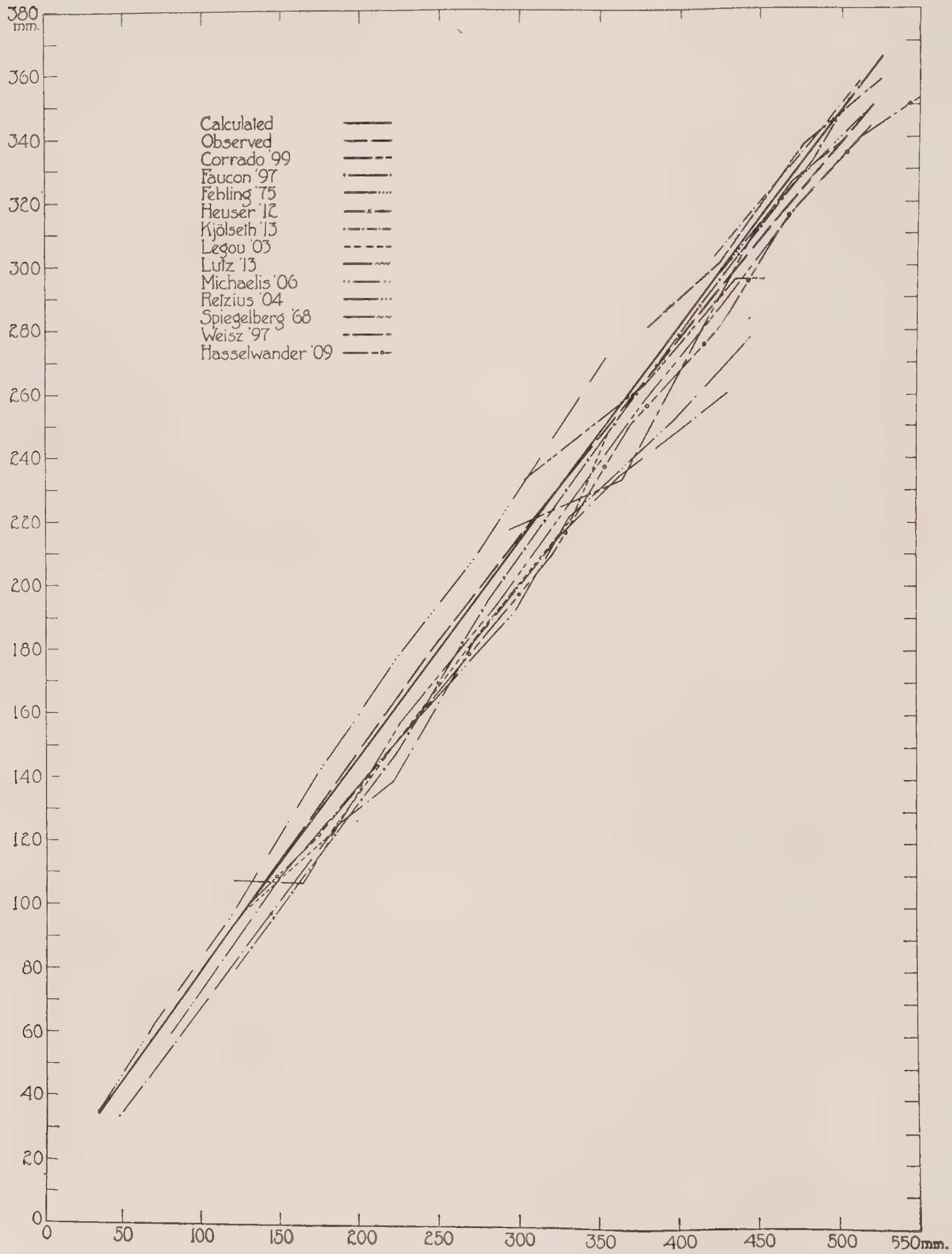
Crown Heel Length (mm.)		Crown Rump Length (mm.)	Horizontal Head Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		C.H Length (cm)	Value (mm)	Per cent. increment
23-50	36.6	31.0	49	26	37.5	37.7	+0.2	+0.5	16	5	46.75	—
50-100	75.4	57.0	76	42	61.9	63.9	+2.0	+3.2	29	10	80.50	72
100-150	124.2	88.9	113	76	95.6	96.8	+1.2	+1.3	45	15	114.25	42
150-200	172.8	119.4	146	107	131.8	129.6	-2.2	-1.7	28	20	148.00	30
200-250	225.3	152.3	194	142	167.1	165.1	-2.0	-1.2	52	25	181.75	24
250-300	273.1	183.9	225	173	199.8	197.3	-2.5	-1.3	46	30	215.50	19
300-350	323.9	223.7	261	204	232.6	231.6	-1.0	-0.4	36	35	249.25	16
350-400	369.9	248.2	293	234	260.2	262.7	+2.5	+1.0	35	40	283.00	14
400-450	423.2	287.9	312	255	290.6	298.7	+8.1	+2.8	29	45	316.75	12
450-500	471.4	318.5	364	288	322.9	331.2	+8.3	+2.6	24	50	350.50	11
500-544	523.4	358.1	373	320	348.5	366.3	+17.8	+5.1	27	55	384.25	10

Table 25 gives the observed and calculated values for this dimension in the fetal period. The deviations of the calculated from the observed values for the 5 cm intervals of crown-heel length are quite small except in the upper ones where birth moulding has a distinct effect upon the dimension. The mean absolute deviations range between 4 and 5 mm, and the mean relative deviations between 1.5 and 2 per cent, depending on the method of determination.

The fetal growth of the horizontal head circumference has been studied by a large number of observers including Arnovljević, Brandt, Corrado, Faucon, Fehling, Hasselwander, Heuser, Kjölseth, Legou, Lind, Lutz, Michaelis, Retzius, Spiegelberg, Sutugin, Weisz,

FIGURE 19

The Growth of the Occipito-Frontal (Horizontal) Circumference of the Head in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Occipito-frontal (horizontal) circumference of the head (mm).

TABLE 26

Average Occipito-Frontal (Horizontal Head) Circumference at Birth

Observer	Average body-length (cm)	Average horizontal head circumference (cm)
Bondyreff (males)	....	34.2
Bondyreff (females)	....	33.4
Bonnifay	49.5	34.4
Breslau	....	34.28
Bumm	....	34.0
Clarke	....	35.08
Daffner (males)	51.2	34.6
Daffner (females)	50.3	34.3
Edgar	....	35.0
Fasbender (males)	48.7	33.6
Fasbender (females)	48.7	33.7
Hecker	51.2	34.66
Hirst	....	34.5
Kjölseth	50.6	35.37
Liharžik (males)	50.0	35.0
Liharžik (females)	49.0	34.0
Mandelstam	48.5	33.9
Meigs	....	33.4
Nagahama (males)	49.0–49.5	32.5–33.5
Nikiforoff (males)	....	35.0
Nikiforoff (females)	....	34.2
Pagliari (males)	49.8	33.2
Pagliari (females)	49.2	32.5
Pfannkuch	48.6	33.4
Popiel	50.5	34.5
Quetelet (males)	50.0	33.5
Quetelet (females)	49.4	33.5
Ranke (males)	49.9	34.7
Ranke (females)	48.6	33.4
Ritter	49.33	33.95
von Ritterschain	50.03	34.50
Runge	....	34.5
Schröder (males)	49.2	34.0
Schröder (females)	48.7	34.3
Spiegelberg (males)	50.9	33.3
Spiegelberg (females)	49.3	32.9
Taylor (males)	51.2	34.7
Taylor (females)	50.0	34.1
Veit	....	35.0
Webster	....	34.0
Weissenberg (males)	50.8	32.7
Weissenberg (females)	50.0	32.6
Weisz	50.0	33.8
Present series (fresh dead)	50.2	32.4
Present series (unmoulded)	50.2	35.0
Present series (calculated)	50.2	35.2

and Witzinger. The values obtained by Retzius are somewhat higher than ours, while those of Faucon and of Corrado are somewhat lower. Our findings are in quite close agreement with the figures of other observers.

The dimension has also been measured in the newborn by a large number of observers, and some averages based upon the major series of cases are given in table 26. It will be seen that our calculated value for the newborn is somewhat higher than those usually reported. Part of this difference may be due to the fact that our calculations of the newborn values are based upon a total body-length of 50.2 cm, which is slightly greater than the average body-lengths of most series of published cases. But most of the difference is obviously due to the correction for birth moulding, which is included in our calculations.

6. Occipito-Frontal Diameter

(Figure 20, Field Graph 3, Tables 27, 28, and 170)

This dimension represents the distance in a straight line from the glabella to the inion or external occipital protuberance. The mechanical error of determination is quite small, for the end-points are definite body landmarks. Injection increases this diameter about 2.5 per cent. Subsequent immersion in formalin increases it still more in the first month, but thereafter there is a gradual decrease, and at the end of six months' preservation a correction of -2.5 per cent will approximate the value for fresh material. Formalin preservation, without injection, apparently does not affect this dimension.

Birth moulding causes a considerable decrease in the occipito-frontal diameter. This is shown by the values of this dimension at 50 cm crown-heel length, in different types of material, which are: fresh specimens, 11.12 cm; injected and preserved specimens, 11.40 cm; and living "unmoulded" heads, 12.10 mm. These figures indicate that this dimension is decreased approximately 1 cm during birth.

Table 27 gives a summary of our findings for this dimension. The calculated values for the 5 cm intervals of body-length, from 5 to 35 cm, inclusive, show very small deviations from the corresponding observed averages. These deviations are increased in the last part of the distribution, where birth moulding becomes an important factor. The mean absolute deviations, as determined by various criteria applied to the several empirical formulae, range from about 1.5 to 2.5 mm. The mean relative deviations fall between 1.2 and 2.5 per cent.

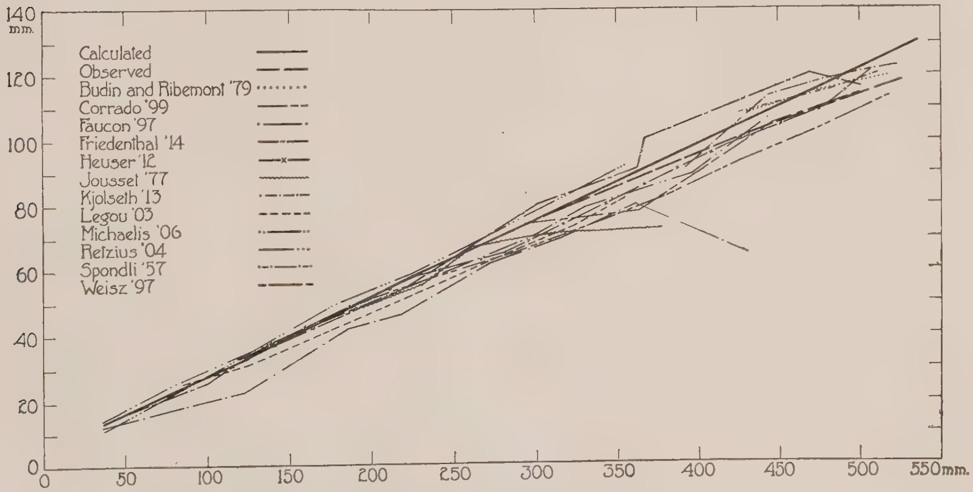
TABLE 27

Occipito-Frontal Diameter of Head (Glabella-Inion)
.235 C.H.(mm.)+4.0mm. (369 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Occipito-Frontal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.		C.H. Length (cm.)	Value (mm.)	Percent increment
23- 50	37.2	31.4	18	10	13.7	12.7	-1.0	-7.3	17	5	15.75	—
50-100	75.4	57.0	27	14	21.7	21.7	0.0	0.0	29	10	27.50	75
100-150	124.2	88.9	39	26	33.2	33.2	0.0	0.0	45	15	39.25	43
150-200	172.8	119.4	51	38	44.7	44.6	-0.1	-0.2	28	20	51.00	30
200-250	225.3	152.3	68	48	57.9	56.9	-1.0	-1.7	52	25	62.75	23
250-300	272.1	183.9	78	60	69.2	68.6	-0.6	-0.9	46	30	74.50	19
300-350	323.9	223.7	90	71	80.0	80.1	+0.1	+0.1	36	35	86.25	16
350-400	370.6	248.2	101	79	88.8	91.1	+2.3	+2.6	36	40	98.00	13
400-450	423.6	287.9	115	87	99.9	103.5	+3.6	+3.6	29	45	109.75	12
450-500	471.4	318.5	123	99	109.2	114.8	+5.6	+5.1	24	50	122.50	10
500-544	523.4	358.1	129	105	117.2	127.0	+9.8	+8.4	27	55	134.25	9

FIGURE 20

The Growth of the Occipito-Frontal Diameter of the Head in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Occipito-frontal diameter of the head (mm).

TABLE 28

AVERAGE OCCIPITO-FRONTAL DIAMETER AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE OCCIPITO-FRONTAL DIAMETER (cm)
Budin and Ribemont	....	11.50
Bondyreff (males)	....	11.6
Bondyreff (females)	....	11.4
De Lee	....	11.0
Fasbender (males)	48.7	11.05
Fasbender (females)	48.2	11.01
Frankenhäuser (males)	....	11.23
Frankenhäuser (females)	....	11.15
Gönner	....	11.75
Hecker	51.12	11.66
Hirst	....	11.75
Hoth (males)	....	11.2
Hoth (females)	....	11.1
Kjölseth	51.0	12.08
Kultz (males)	....	11.6
Kultz (females)	....	11.3
Lafaille	49.3	11.67
Legou	....	12.00
Liharžik (males)	50.0	12.0
Liharžik (females)	49.0	11.5
Mandelstam	....	11.27
Meigs	....	12.28
Nikiforoff (males)	....	12.20
Nikiforoff (females)	....	11.40
Popiel	50.3	11.0
Quetelet (males)	50.0	12.0
Quetelet (females)	49.4	12.0
Ranke (males)	49.9	12.1
Ranke (females)	48.6	11.8
Schröder (males)	49.2	11.88
Schröder (females)	48.7	11.76
Solares	49.9	11.7
Spiegelberg (males)	50.9	11.52
Spiegelberg (females)	49.3	11.28
Stratz	....	11.75
Tarnier and Chantreuil	....	11.00
Van Pelt	....	11.94
Weisz	50.0	11.40
Williams	....	11.75
Present series (fresh dead)	50.2	11.2
Present series (unmoulded)	50.2	12.1
Present series (calculated)	50.2	12.2

The growth of this dimension in the fetus has been studied by Budin and Ribemont, Caspar, Corrado, Depaul, Faucon, Friedenthal, Heuser, Jousset, Kjölseth, Lafaille, Legou, Michaelis, Retzius, Solares, Spondli, and Weisz. These studies are summarized in table 170. Both Corrado and Faucon obtained results that are distinctly lower than ours, while those of Friedenthal are somewhat higher. The results of all other observers, while quite irregular, agree fairly well with our findings and with one another.

Since occipito-frontal diameter is an important obstetrical and anthropological measurement there are a large number of published averages of this dimension for the newborn. Some of the more important ones are given in table 28, together with our findings for the newborn.

7. Suboccipito-Bregmatic Circumference

(Figure 21, Field Graph 4, Tables 29, 30, and 171)

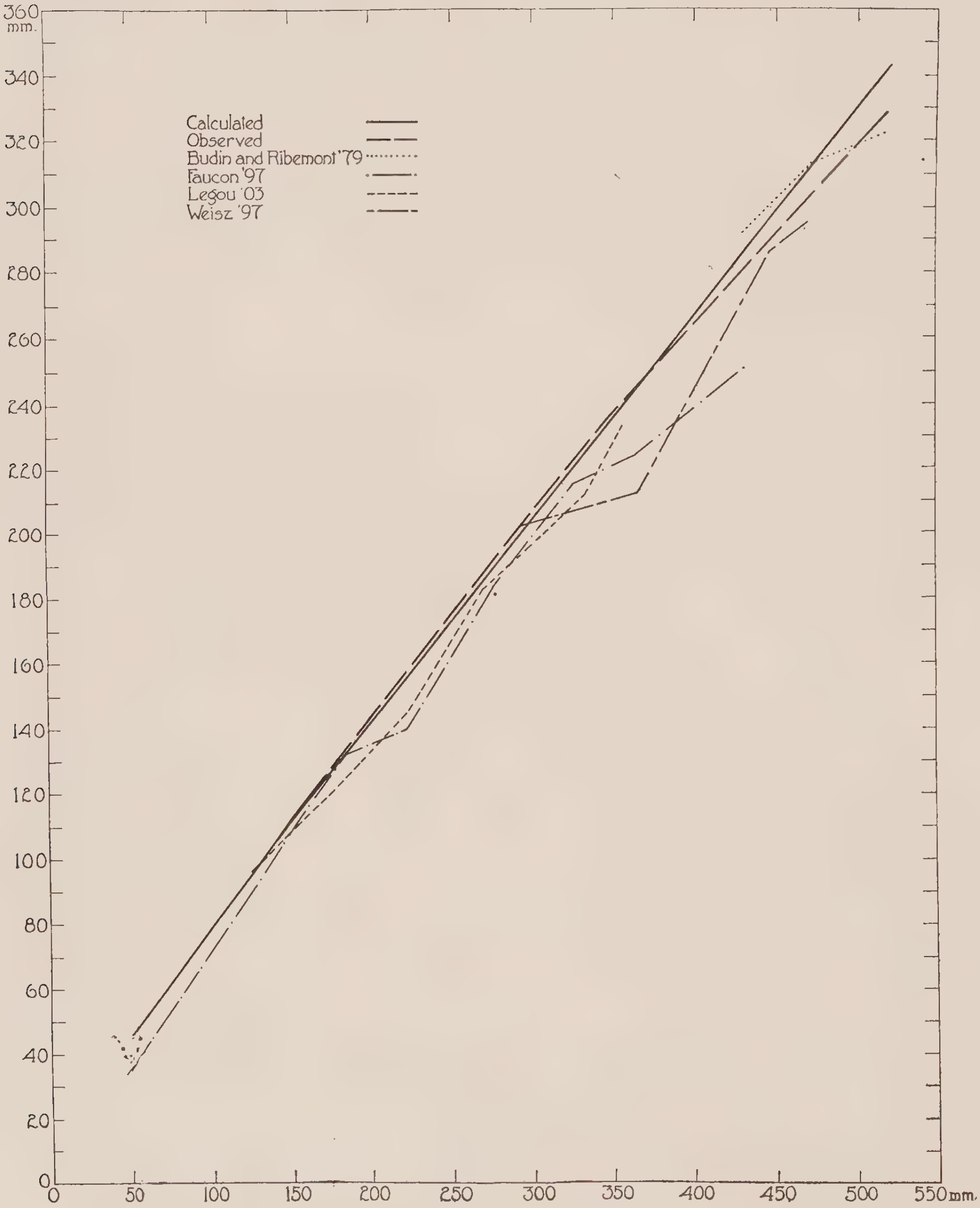
This dimension was measured through the same landmarks used for the corresponding diameter and described in connection with it. The mechanical errors of measurement are rather large, as neither landmark is absolutely definite, but the deviations are probably largely compensatory. Injection increases this measurement about 4.5 per cent and the correction necessary after six months' immersion in formalin following injection is also +4.5 per cent. In the small series of cases studied, simple immersion in 10 per cent formalin solution for six months caused an increase of 2.5 per cent.

This circumference seems more affected than any other by birth moulding. The values at 50 cm crown-heel length, in different classes of material are: fresh specimens, 30.2 cm; injected and preserved specimens, 31.6 cm; and living "unmoulded" heads, 32.5 cm. These indicate a decrease of approximately 2 cm through head moulding.

The observed and calculated values for this dimension are summarized in table 29. The values calculated by our empirical formulae show two types of deviations from the corresponding observed averages for the 5 cm intervals of crown-heel length. In the middle third of the progression the calculated values are less than the observed to about the extent indicated by the estimated preservation change produced by immersion in formalin without injection, and they are probably to be accounted for on this basis. The deviations

FIGURE 21

THE GROWTH OF THE SUBOCCIPITO-BREGMATIC CIRCUMFERENCE OF THE HEAD IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Suboccipito-bregmatic circumference of the head (mm).

in the last third of the progression are of the type encountered in all of the obstetrical dimensions of the head, and are commensurate in kind and amount with the change produced by birth moulding. The average deviations of the calculated values from the corresponding

TABLE 29

Suboccipito Bregmatic Circumference of Head
.625 C.H.(mm.) + 16.0 mm. (365 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Suboccipito Bregmatic Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent.		C.H. Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.6	31.0	48	28	37.4	38.9	+ 1.5	+4.0	16	5	47.25	—
50-100	75.4	57.0	76	41	61.7	63.1	+ 1.4	+2.3	29	10	78.50	66
100-150	124.1	88.8	110	75	94.6	93.6	- 1.0	-1.1	44	15	109.75	40
150-200	172.8	119.4	140	106	124.0	124.0	0.0	0.0	28	20	141.00	28
200-250	225.3	152.3	184	130	160.2	156.8	- 3.4	- 2.1	52	25	172.25	22
250-300	273.5	184.1	210	161	191.3	186.9	- 4.4	- 2.3	45	30	203.50	18
300-350	323.9	223.7	247	195	222.2	218.4	- 3.8	- 1.7	36	35	234.75	15
350-400	369.9	248.2	281	221	248.3	247.2	- 1.1	-0.4	35	40	266.00	13
400-450	423.2	287.9	291	246	273.2	280.5	+ 7.3	+2.7	29	45	297.25	12
450-500	471.4	318.5	352	262	303.8	310.6	+ 6.8	+2.2	24	50	328.50	11
500-544	523.4	358.1	347	308	326.3	343.1	+16.8	+5.1	27	55	359.75	10

TABLE 30

Average Suboccipito-Bregmatic Circumference of the Head at Birth

Observer	Average body-length (cm)	Average suboccipito-bregmatic circumference (cm)
Budin and Ribemont	....	32.34
Bumm	....	32.0
Edgar	....	28.0
Hirst	....	30.0
Mandelstam	48.5	30.4
Webster	....	30.0
Present series (fresh dead)	50.2	30.3
Present series (unmoulded)	50.2	32.7
Present series (calculated)	50.2	33.0

observed means for 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, range from about 3.7 to 4.8 mm. The corresponding average relative deviations are of the order of 2 per cent.

The growth of this dimension in the fetal period has been previously studied by Budin and Ribemont, Legou, Faucon, and Weisz. The last two observers obtained values that are slightly below our averages, while our observations correspond very closely with those of the first two investigators.

The published values of this circumference in the newborn, together with our natal values, as estimated by the empirical formula with graphically determined constants, are given in table 30.

8. Suboccipito-Bregmatic Diameter

(Figure 22, Field Graph 5, Tables 31, 32, and 171)

This dimension is the distance from the junction of the sagittal and coronal sutures to the junction of the superior and lateral portions of the occipital bone. The determination of this dimension is liable to some mechanical error in individual cases, but the deviations are probably largely compensatory. Injection increases this diameter about 3.8 per cent. Immersion in formalin after injection causes an early increase, which is followed later by a decrease, so that at the

TABLE 31

SUBOCCIPITO-BREGMATIC DIAMETER OF HEAD
.2 C.H. (MM.) + 6.0 MM. (368 CASES)

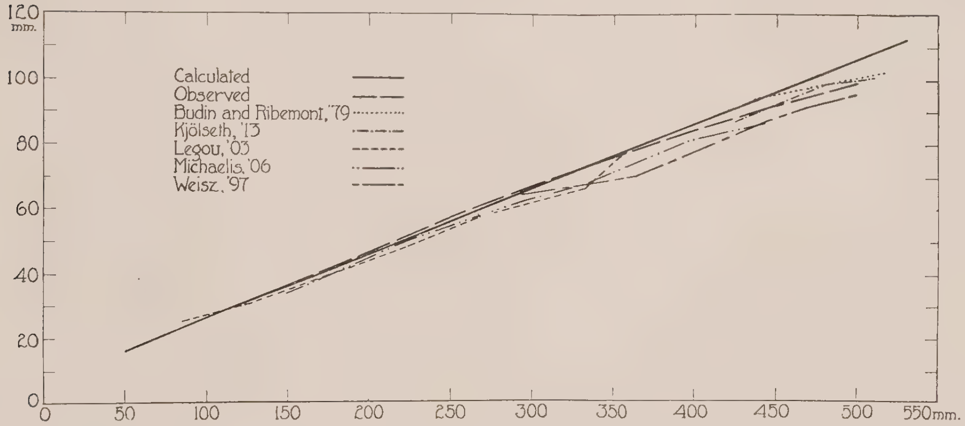
Crown Heel Length (mm.)		Crown Rump Length (mm.)	Suboccipito Bregmatic Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max	Min.	Mean (a)		mm.	Per cent		C.H. Length (cm.)	Value (mm.)	Per cent increment
23-50	37.2	31.4	17	9	13.2	13.4	+0.2	+1.5	17	5	16.0	—
50-100	75.4	57.0	25	12	21.0	21.1	+0.1	+0.5	29	10	26.0	63
100-150	124.2	88.9	40	24	31.4	30.8	-0.6	-1.9	45	15	36.0	38
150-200	172.8	119.4	48	37	41.6	40.6	-1.0	-2.4	28	20	46.0	28
200-250	225.3	152.3	63	43	52.5	51.1	-1.4	-2.7	52	25	56.0	22
250-300	273.5	184.1	70	51	61.8	60.7	-1.1	-1.8	45	30	66.0	18
300-350	323.9	223.7	82	62	71.0	70.8	-0.2	-0.3	36	35	76.0	15
350-400	370.6	248.2	88	67	79.9	80.1	+0.2	+0.3	36	40	86.0	13
400-450	423.2	287.9	96	78	87.9	90.6	+2.7	+3.1	29	45	96.0	12
450-500	471.4	318.5	109	83	95.2	100.3	+5.1	+5.4	24	50	106.0	10
500-544	523.4	358.1	110	94	102.3	110.7	+8.4	+8.2	27	55	116.0	9

end of six months' preservation a correction of −3.6 per cent will approximate the true value. Simple preservation in formalin alone produces practically no change in this diameter.

Birth moulding causes a considerable decrease in this diameter, and therefore measurements of this dimension in the injected specimens really represent more nearly the condition of the living fetus in utero than do those made on fresh specimens. The measurements at 50 cm crown-heel length in different types of material are: fresh specimens, 9.55 cm; injected and preserved specimens, 9.90 cm; living "unmoulded" heads, 10.40 cm. Thus birth moulding apparently causes an average decrease of about 8 or 9 mm in the diameter.

FIGURE 22

The Growth of the Suboccipito-Bregmatic Diameter of the Head in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Suboccipito-bregmatic diameter of the head (mm).

Table 31 gives a summary of our observed and calculated values for this dimension. The calculated means for 5 cm intervals of crown-heel length show deviations from the corresponding observed means that are mainly confined to the last trimester of pregnancy and are apparently due largely to birth moulding. The mean deviations of the calculated from the observed values of the 5 cm intervals, from 5 to 55 cm, inclusive, are of the order of 2 mm or less. The mean relative deviations range from 2.3 to about 2.7 per cent.

The growth of this diameter in the fetal period has been studied by Budin and Ribemont, Depaul, Kjölseth, Lafaille, Legou, Michaelis, Solares, and Weisz. Our findings are in fairly close agreement with those of most of these observers, although the values given by Weisz are distinctly below those that we obtained. The means of the major series of published values for this dimension at birth are given in table 32.

TABLE 32

Average Suboccipito-Bregmatic Diameter of the Head at Birth

Observer	Average body-length (cm)	Average suboccipito-bregmatic diameter (cm)
Budin	....	10.3
Budin and Ribemont	....	10.0
Bumm	....	9.5
Edgar	....	9.5
Gönner	....	9.5
Kjölseth	....	10.6
Grillenzoni	....	10.0
Lafaille	49.3	9.7
Legou	....	9.5
Malgaigne	....	9.5
von Skalkowski	....	10.3
Solares	49.9	9.7
Stratz	....	9.5
Tarnier and Chantreuil	....	9.5
Webster	....	10.3
Weisz	50.0	9.5
Present series (calculated)	50.2	10.6

9. Suboccipito-Frontal Circumference

(Figure 23, Field Graph 6, Tables 33, and 172)

This circumference was taken through the same bony landmarks as the corresponding diameter. The mechanical errors of determination are small and are probably largely compensatory. Injection produces a primary increase of about 5 per cent in dimension, while subsequent immersion in formalin causes a further enlargement to nearly 7 per cent in the first month. After this there is a gradual decrease, and the necessary correction to obtain the fresh value at six months is about 5.6 per cent. Immersion in formalin, without injection, causes an increase of nearly 2 per cent in two or three months. There seems to be little change after this time.

Head moulding produces a decrease in this dimension at birth that is comparable to that of the suboccipito-bregmatic circumference and amounts to about 2.5 cm. At 50.0 cm crown-heel length, the values of the circumference in the three types of material studied are: fresh specimens, 30.9 cm; injected and preserved specimens, 32.7 cm; living "unmoulded" heads, 33.4 cm.

Table 33 gives our observed and calculated values for this circumference in the fetal period. The calculated values for the 5 cm intervals of body-length show the two types of deviation from the observed means that have been described in connection with the suboccipito-bregmatic circumference. In the middle third of the progression the observed means are somewhat larger than the calculated ones that correspond to the increase produced by the artifact of formalin preservation. In the last third of the progression the deviations are of the type noted in the other circumferences of the head, and correspond in amount and direction to the changes produced by head moulding. Most of the deviations of the calculated from the observed means of the 5 cm intervals from 5 to 55 cm of crown-heel length, inclusive, are of the order of 5 mm and of 2.5 per cent.

TABLE 33

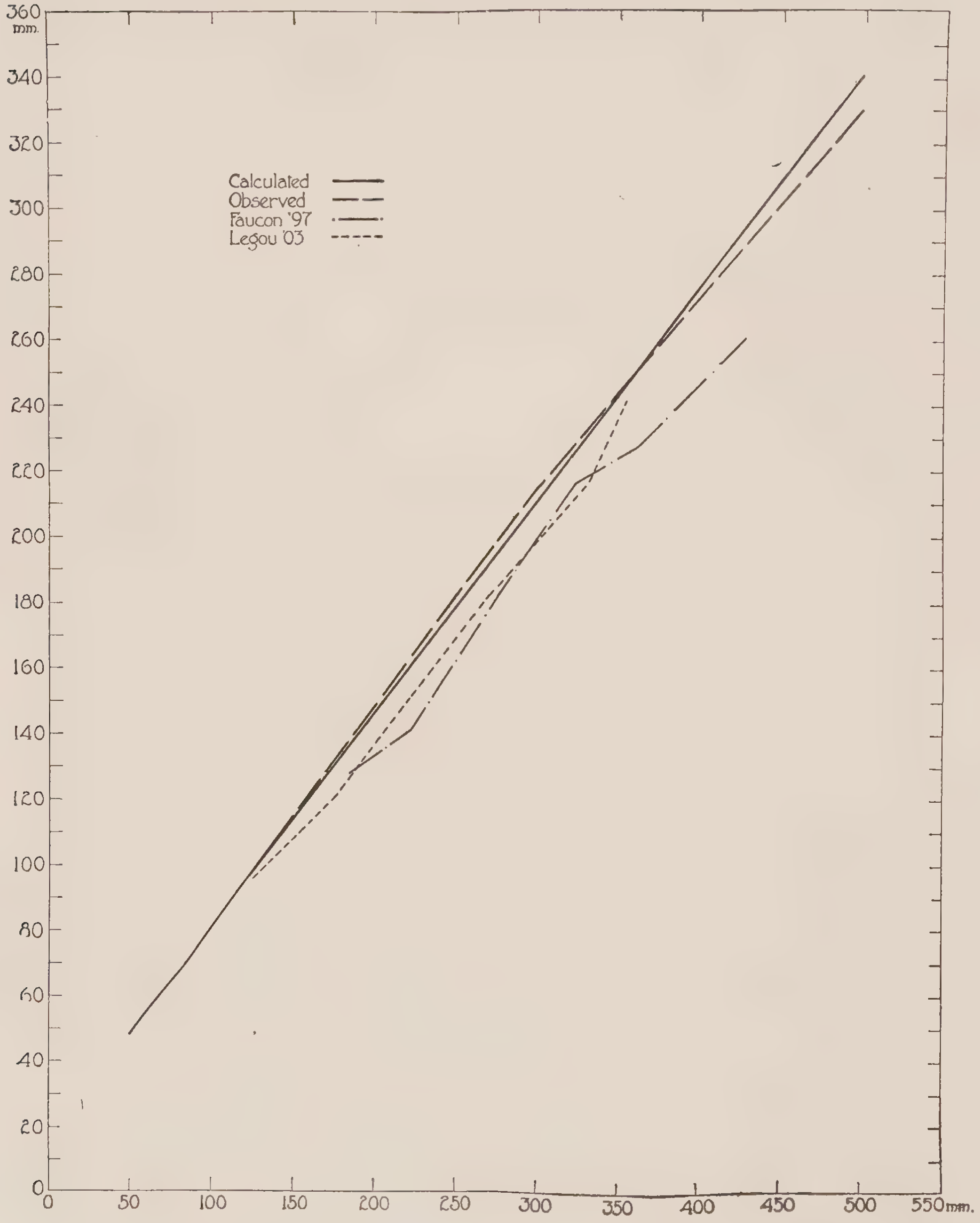
SUBOCCIPITO-FRONTAL CIRCUMFERENCE OF HEAD
.65 C.H. (MM.) + 15.0 MM. (366 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Suboccipito Frontal Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max	Min	Mean (a)		mm.	Per cent.		C.H. Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.6	31.0	50	28	39.0	38.8	-0.2	-0.5	16	5	47.5	—
50-100	75.4	57.0	78	45	62.9	64.0	+1.1	+1.7	29	10	80.0	68
100-150	124.2	88.9	115	75	96.8	95.7	-1.1	-1.1	45	15	112.5	41
150-200	172.8	119.4	143	111	132.7	127.3	-5.4	-4.1	28	20	145.0	29
200-250	225.3	152.3	192	141	166.5	161.4	-5.1	-3.1	52	25	177.5	22
250-300	273.5	184.1	224	170	197.7	192.8	-4.9	-2.5	45	30	210.0	18
300-350	323.9	223.7	257	201	227.8	225.5	-2.3	-1.0	36	35	242.5	15
350-400	369.9	248.2	284	225	254.5	255.4	+0.9	+0.4	35	40	275.0	13
400-450	423.2	287.9	300	248	280.3	290.1	+9.8	+3.5	29	45	307.5	12
450-500	471.4	318.5	354	280	312.3	321.4	+9.1	+2.9	24	50	340.0	11
500-544	523.4	358.1	367	319	338.9	355.2	+16.3	+4.8	27	55	372.5	10

Both Faucon and Legou, who have published data on this dimension in the fetal period, obtained values that are somewhat smaller

FIGURE 23

THE GROWTH OF THE SUBOCCIPITO-FRONTAL CIRCUMFERENCE OF THE HEAD IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Suboccipito-frontal circumference of the head (mm) than our figures. We have found no published records of the value of this circumference at birth, except a figure of 30.0 cm given by Edgar. Our figures for the newborn are: for fresh dead material, 31.1 cm; for the living "unmoulded" heads, 33.7 cm; and calculated by empirical formula, with graphically determined constants, 34.1 cm.

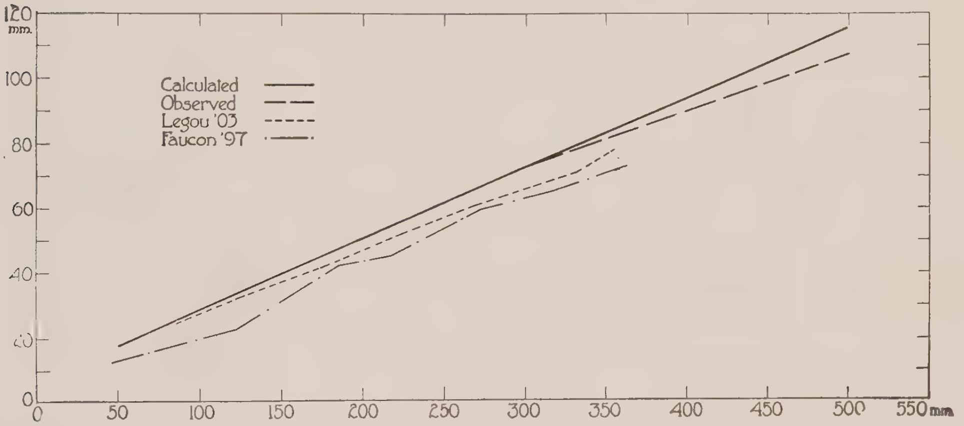
10. Suboccipito-Frontal Diameter

(Figure 24, Field Graph 7, Tables 34, 35, and 171)

This measurement was taken from the junction of the superior and lateral portions of the occipital bone, posteriorly, to the most distant point in the sagittal suture, anteriorly. The mechanical error in the determination of this measurement is much smaller than that of the suboccipito-bregmatic diameter and is probably equally compensatory in character. Injection causes an increase of 4.3 per cent in the measurement. Immersion in formalin, following injection, produces a temporary increase of 6.0 per cent at the first month, and later, a gradual decrease to 4.9 per cent at six months. Simple preservation in formalin produces a very small increase in the series of cases studied.

FIGURE 24

The Growth of the Suboccipito-Frontal Diameter of the Head in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Suboccipito-frontal diameter of the head (mm).

Birth moulding produces a decrease of about a centimeter in this dimension. This is shown by the following measurements at 50.0 cm crown-heel length: fresh specimens, 11.2 cm; injected and preserved specimens, 10.7 cm; living "unmoulded" heads, 11.3 cm.

TABLE 34

SUBOCCIPITO-FRONTAL DIAMETER OF HEAD
215 C.H. (MM.) + 7.0 MM. (368 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm.)	Suboccipito-Frontal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min	Mean (a)		mm	Percent.		C H Length (cm)	Value (mm.)	Per cent increment
23-50	37.2	31.4	18	10	14.5	149	+0.4	+2.8	17	5	17.75	—
50-100	75.4	57.0	28	15	22.4	23.2	+0.8	+3.6	29	10	28.5	61
100-150	124.2	88.9	41	25	33.6	337	+0.1	+0.3	45	15	39.25	38
150-200	172.8	119.4	50	38	44.8	442	-0.6	-1.3	28	20	50.00	27
200-250	225.3	152.3	65	47	56.9	55.4	-1.5	-2.6	52	25	60.75	22
250-300	273.2	184.1	77	58	67.1	65.8	-1.3	-1.9	45	30	71.50	18
300-350	323.9	223.7	87	68	76.3	76.6	+0.3	+0.4	36	35	82.25	15
350-400	370.6	248.2	97	73	85.1	86.7	+1.6	+1.9	36	40	93.00	13
400-450	423.2	287.9	108	82	93.6	980	+4.4	+4.7	29	45	103.75	12
450-500	471.4	318.5	115	89	102.4	108.4	+6.0	+5.9	24	50	114.50	10
500-544	523.4	358.1	118	99	111.0	119.5	+8.5	+7.7	27	55	125.25	9

TABLE 35

AVERAGE SUBOCCIPITO-FRONTAL DIAMETER AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE SUBOCCIPITO-FRONTAL DIAMETER (cm)
Edgar	....	11.0
Grillenzoni	....	10.35
Hecker	51.2	11.66
Lafaille	49.3	10.63
Legou	....	11.0
Webster	....	11.0
Present series (calculated)	50.2	11.5

Our data on this dimension are summarized in table 34. The calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations from the corresponding observed means of the order of 2.0 to 2.5 mm. The root mean square deviations vary from 1 to nearly 4 mm. The mean relative deviations range between 2.7 and 3 per cent. Most of this deviation is in the last part of the distribution where head moulding affects the dimension.

The growth of this dimension in the fetus has been studied by Legou and Faucon, both of whom obtained values that are distinctly lower than ours, and by Lafaille whose figures are very close to our values. The means for the diameter in the newborn, as determined by several observers, as well as our findings, are given in table 35.

11. Occipito-Mental Circumference

(Field Graph 8, Tables 36 and 172)

This dimension was taken through the same points as the corresponding diameter. The error of measurement is rather larger, absolutely and relatively, than that for the diameter. It is questionable if this error is compensatory. Formalin injection produces an increase of 7.7 per cent in the occipito-mental circumference. Subsequent immersion in formalin raises this figure to 9.8 per cent by the end of the second month. Thereafter there is a gradual decrease so that the correction figure, after six months' preservation, is −6.6 per cent. Immersion in formalin without previous injection gave questionable results in a small series of cases studied. Birth moulding seems to have comparatively little effect upon this dimension.

Table 36 summarizes our findings and computations for the occipito-mental circumference. The mean absolute deviations of our calculated values from the corresponding observed averages for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 3.4 to about 4 mm. The root mean square deviations are a little over 4 mm. The majority of the various measures of the mean percentage deviations are of the order of 2.5 per cent.

Budin and Ribemont, and Weisz have recorded observations on the growth in fetal life of a dimension that they term the "occipito-mental circumference." However, their measurements were made through the lambda and not the occiput, and their dimension corresponds to our "large circumference" rather than to the "occipito-mental circumference" as here defined. The findings of these authors are therefore considered in connection with the "large circumference." We do not think that the occipito-mental circumference, as we have defined it, is a particularly reliable measurement, and we much prefer the "large circumference" as a determination of the perimeter of the head in this general plane.

Our values for this dimension in the newborn (at 50.2 cm crown-heel length) are: 29.6 cm for fresh specimens; 31.5 cm for living "unmoulded" heads; and 32.5 cm according to our empirical formula, as determined by graphic methods.

TABLE 36

Occipito-Mental Circumference of Head (Menton-Inion)
.63 C.H. (mm.) + 9.0 mm. (355 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Occipito-Mental Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.		C.H. Length (cm.)	Value (mm.)	Per cent increment
23-50	35.9	30.5	47	23	33.4	31.6	-1.8	-5.4	15	5	40.5	—
50-100	75.4	57.0	73	40	53.6	56.5	+2.9	+5.4	29	10	72.0	78
100-150	123.5	88.4	101	63	83.5	86.8	+3.3	+4.0	43	15	103.5	44
150-200	172.8	119.4	135	95	117.5	117.9	+0.4	+0.3	28	20	135.0	30
200-250	225.3	152.3	181	125	156.0	150.9	-5.1	-3.3	50	25	166.5	23
250-300	273.1	183.9	217	162	186.6	181.1	-5.5	-2.9	46	30	198.0	19
300-350	323.9	223.7	257	190	219.8	213.1	-6.7	-3.0	36	35	229.5	16
350-400	369.9	248.2	279	213	245.9	242.0	-3.9	-1.6	35	40	261.0	14
400-450	423.5	288.1	297	230	270.9	275.8	+4.9	+1.8	28	45	292.5	12
450-500	471.5	318.3	367	269	308.4	306.0	-2.4	-0.8	23	50	324.0	11
500-544	525.3	358.4	380	307	336.2	339.9	+3.7	+1.1	22	55	355.5	9

12. Occipito-Mental Diameter

(Figure 25, Field Graph 9, Tables 37, 38, and 172)

This dimension is the distance in a straight line from menton to inion, i.e., from the point of the chin to the external occipital protuberance. The error of determination is due largely to the variation in the position of the lower jaw. This is greatly reduced by placing the jaws in normal approximation before taking the measurement. The dimension is increased about 4.8 per cent by injection, and subsequent immersion in formalin causes a further increase to 6.0 per cent in the first month. This is followed by a gradual decrease to 2.9 per cent at the end of six months. Preservation in formalin without injection produces little or no change in this diameter.

A priori, one would expect an increase in this dimension through birth moulding; but we find little evidence of such change. The figures for the diameter at 50 cm crown-heel length are: fresh specimens, 11.7 cm; injected and preserved specimens, 11.9 cm; living "unmoulded" heads, 11.9 cm.

Our summarized findings for this dimension are given in table 37. The calculated values for the means of the 5 cm intervals of crown-heel length, as determined from our empirical formulae, show small deviations from the observed values, throughout the distribution. The mean absolute deviations are of the order of 1 mm and the relative deviations are all less than 2 per cent.

TABLE 37

OCCIPITO MENTAL DIAMETER OF HEAD (MENTON-INION)
.235 C.H. (MM.) + 2.0 MM. (365 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Occipito-Mental Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent		C H Length (cm)	Value (mm)	Per cent increment
23-50	36.6	30.9	16	8	12.1	10.6	-1.5	-12.4	16	5	13.75	—
50-100	75.4	57.0	25	14	20.1	19.7	-0.4	-2.0	29	10	25.50	85
100-150	124.2	88.9	36	24	30.5	31.2	+0.7	+2.3	45	15	3725	46
150-200	172.8	1194	48	37	42.1	42.6	+0.5	+1.2	28	20	4900	32
200-250	225.3	152.3	66	47	56.1	54.9	-1.2	-2.1	50	25	6075	24
250-300	273.5	184.1	76	58	67.8	66.3	-1.5	-2.2	45	30	72.50	19
300-350	323.9	223.7	88	70	79.5	78.1	-1.4	-1.8	36	35	84.25	16
350-400	370.6	248.2	104	82	89.6	89.1	-0.5	-0.6	36	40	9600	14
400-450	423.2	287.9	107	89	100.2	101.5	+1.3	+1.3	29	45	10775	12
450-500	471.4	318.5	129	103	112.7	112.8	+0.1	+0.1	24	50	119.5	11
500-544	523.4	358.1	142	112	123.4	125.0	+1.6	+1.3	27	55	131.25	10

The growth of this dimension in the fetal period has been previously studied by Budin and Ribemont, Cadre, Corrado, Depaul, Faucon, Kjölseth, Lafaille, Legou, Michaelis, Solares, Spondli, and Weisz. The findings are in close agreement with ours except in instances where different techniques of measurement were employed and the lesser fontanelle was used as the posterior end-point of the diameter instead of the external occipital protuberance.

Nearly all observers who have studied this diameter of the head in the newborn have made use of the lesser or occipital fontanelle as the posterior end-point of the measurement. Consequently their findings are uniformly greater than our natal values. Some of the more important averages are given in table 38.

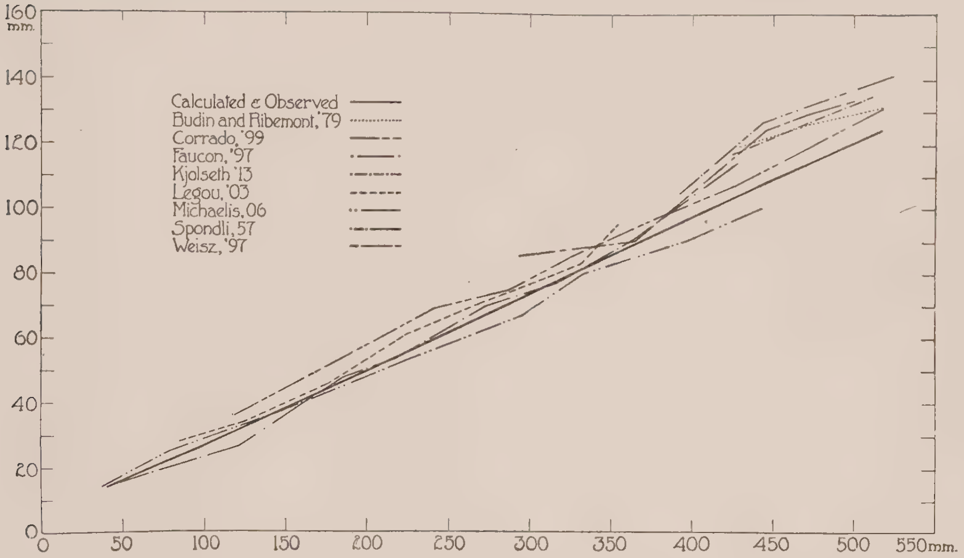
TABLE 38

AVERAGE OCCIPITO-MENTAL DIAMETER OF THE HEAD AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE OCCIPITO-MENTAL DIAMETER (cm)
Budin	....	12.4
Budin and Ribemont	....	13.0
Bumm	....	13.5
Cadre	48.4	13.73
De Lee	....	13.0
Edgar	....	14.0
Gönner	....	13.5
Hecker	51.2	13.38
Hirst	....	13.0
Hoth (males)	....	12.9
Hoth (females)	....	12.8
Kjölseth	....	13.46
Kultz (males)	....	13.5
Kultz (females)	....	13.4
Lafaille	49.3	13.12
Legou	....	13.0
Malgaigne	....	13.5
Mandelstam	48.5	12.56
Popiel	50.5	13.0
Quetelet	49.7	13.4
Schönberg	....	13.0
Schröder (males)	49.2	13.59
Schröder (females)	48.7	13.47
Solares	49.9	13.5
Spiegelberg	50.18	13.3
Stratz	....	13.5
Tarnier and Chantreuil	....	13.0
Van Pelt	....	13.78
Webster	....	12.5
Weisz	50.0	13.35
Williams	....	13.5
Present series (fresh dead)	50.2	11.6
Present series (unmoulded)	50.2	11.9
Present series (calculated)	50.2	12.0

FIGURE 25

THE GROWTH OF THE OCCIPITO-MENTAL DIAMETER OF THE HEAD IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Occipito-mental diameter of the head (mm).

13. Large Circumference (Menton-Lambda)

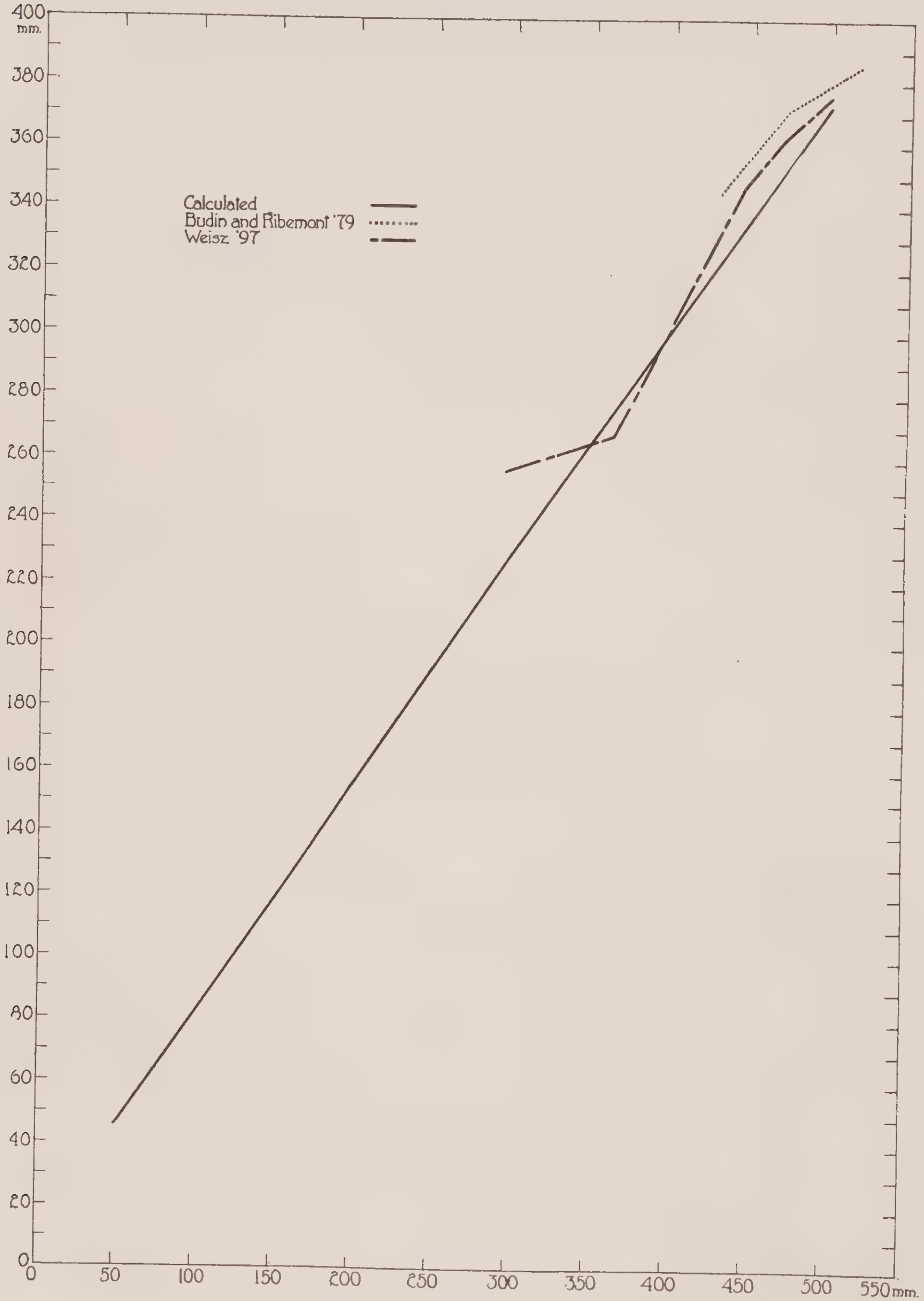
(Figure 26, Field Graph 10, Tables 39, 40, and 172)

This circumference was taken through the lesser (occipital) fontanelle and the menton. It is a much more reliable measurement than the preceding occipito-mental circumference, and its determination is attended with less mechanical difficulty. Injection increases this measurement about 5.4 per cent, and subsequent immersion in formalin causes a continued increase to about 7 per cent in the first month. Thereafter there is a gradual decrease, the formalin correction after six months' preservation being −4.7 per cent. Simple immersion in formalin, without injection, produces little change.

Birth moulding appears to have comparatively little effect upon this circumference. At 50 cm crown-heel length the values for this circumference in the three types of material studied are: fresh specimens, 35.3 cm; injected and preserved specimens, 37.0 cm; living "unmoulded" heads, 33.4 cm. These figures indicate that a possible decrease of about 1 cm may result from the birth process.

FIGURE 26

The Growth of the Large Circumference of the Head in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Large circumference of the head (mm).

Table 39 gives our findings for this circumference. The calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations ranging from about 2 to almost 10 mm from the corresponding observed means. The corresponding average relative deviations range from about 1 to about 5 per cent. These deviations are fairly equally distributed throughout the progression.

TABLE 39

LARGE CIRCUMFERENCE OF HEAD (MENTON-LAMBDA)
.72 C.H. (MM.) + 10.0 MM. (343 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Large Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				C H Length (cm.)	Value (mm)	Per cent increment
Range	Mean		Max	Min.	Mean (a)		mm.	Per cent				
23-50	35.9	30.5	46	27	36.7	35.8	-0.9	-2.5	15	5	46.0	—
50-100	75.4	57.0	78	44	62.0	64.3	+2.3	+3.7	29	10	82.0	78
100-150	123.5	88.4	112	79	96.8	98.9	+2.1	+2.2	42	15	118.0	44
150-200	173.2	119.6	153	116	134.6	134.7	+0.1	+0.1	27	20	154.0	31
200-250	225.3	152.3	199	149	174.7	172.2	-2.5	-1.4	50	25	190.0	23
250-300	271.7	182.1	233	182	207.4	205.6	-1.8	-0.9	43	30	226.0	19
300-350	323.9	223.7	282	214	246.1	243.2	-2.9	-1.2	36	35	262.0	16
350-400	369.5	248.6	300	253	276.2	276.0	-0.2	-0.1	33	40	298.0	14
400-450	421.8	286.3	335	278	310.9	313.7	+2.8	+0.9	23	45	334.0	12
450-500	474.0	321.0	402	330	355.3	351.3	-4.0	-1.1	20	50	370.0	11
500-544	523.3	359.2	407	358	383.9	386.8	+2.9	+0.8	25	55	406.0	10

TABLE 40

AVERAGE LARGE CIRCUMFERENCE OF THE HEAD (MENTON-LAMBDA) AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE LARGE CIRCUMFERENCE (cm)
Budin	....	37.6
Bumm	....	35.0
Edgar	....	38.0
Hirst	....	37.0
Webster	....	35.5
Weisz	....	37.45
Present series (fresh dead)	50.2	35.5
Present series (unmoulded)	50.2	36.5
Present series (calculated)	50.2	37.1

The growth of this dimension in the latter part of the fetal period has been studied by Budin and Ribemont and by Weisz. The values of the former investigators are distinctly higher than ours. Those of Weisz, while quite irregular, show a closer approach to our findings. The values for this circumference in the newborn are summarized in table 40.

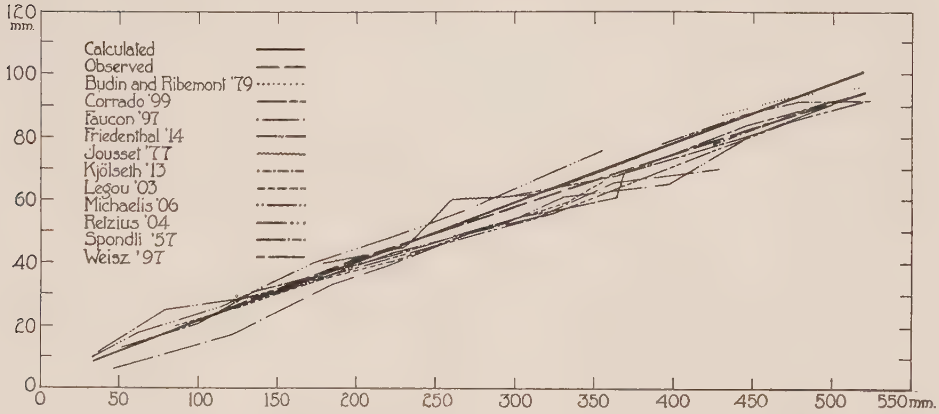
14. Bi-Parietal Diameter

(Figure 27, Field Graph 11, Tables 41, 42, and 173)

This dimension is defined as the greatest width of the head between the parietal eminences. The mechanical error of determination is small, for the end-points are definite bony landmarks. Injection increases this dimension about 4.4 per cent, but subsequent preservation causes a slow shrinkage, and the formalin correction figure, after six months' preservation, is −3.6 per cent. Preservation, without injection, produces almost no change in this dimension.

FIGURE 27

The Growth of the Bi-Parietal Diameter of the Head in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Bi-parietal diameter of the head (mm).

The bi-parietal diameter is distinctly affected by birth moulding. The values of this dimension, at 50.0 cm crown-heel length, in the three types of material studied are: fresh specimens, 8.77 cm; injected and preserved specimens, 9.10 cm; living "unmoulded" heads, 9.60 cm.

Table 41 summarizes our findings for this measurement. The calculated values, as computed from our several empirical formulae, for the 5 cm intervals from 5 to 55 cm, inclusive, of crown-heel length, show average absolute deviations of the order of 2 mm or less. The corresponding average relative deviations range from over 2 per cent to over 3 per cent. The dimension is much decreased by head moulding between 35 and 55 cm crown-heel length, and the deviations of the calculated means are therefore augmented in this part of the progression.

The growth of the bi-parietal diameter in the fetus has been studied by Budin and Ribemont, Cadre, Calderini, Caspar, Corrado, Depaul, Faucon, Friedenthal, Jousset, Kjölseth, Lafaille, Legou, Michaelis, Retzius, Solares, Spondli, Sutugin, Weisz, and others. The agreement of our findings with the results of these observers is quite close in most instances, although our figures are distinctly higher than those of Faucon and of Corrado and distinctly lower than those of Retzius and of Jousset.

TABLE 41

BI-PARIETAL DIAMETER OF HEAD (MAXIMUM)
.19 C.H.(MM.) + 2.0 MM. (369 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Bi-Parietal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm.	Per cent.		C.H. Length (cm)	Value (mm)	Per cent. increment
23-50	37.2	31.4	12	6	9.5	9.1	-0.4	-4.2	17	5	11.5	—
50-100	75.4	57.0	20	10	16.2	16.3	+0.1	+0.6	29	10	21.0	83
100-150	124.2	88.9	32	21	26.3	25.6	-07	-2.7	45	15	30.5	45
150-200	172.8	119.4	41	29	35.5	34.8	-0.7	-2.0	28	20	40.0	31
200-250	225.3	152.3	54	35	45.3	44.8	-0.5	-1.1	52	25	49.5	24
250-300	273.1	183.9	66	43	53.9	53.9	0.0	0.0	46	30	59.0	19
300-350	323.9	223.7	77	52	62.5	63.5	+1.0	+1.6	36	35	68.5	16
350-400	370.6	248.2	78	58	69.6	72.4	+2.8	+40	36	40	78.0	14
400-450	423.2	287.9	84	66	77.3	82.4	+5.1	+6.6	29	45	87.5	12
450-500	471.4	318.5	99	70	87.0	91.6	+4.6	+5.3	24	50	97.0	11
500-544	523.4	358.1	102	85	940	101.4	+7.4	+7.9	27	55	106.5	10

There are many published averages of the natal value of this dimension. Some of the more important of these figures, together with our findings, are included in table 42.

15. Auriculo-Vertex-Auricular Circumference

(Field Graph 12, Tables 43 and 44)

This dimension may be defined as a perimetric line between the two auditory meatus passing through the vertex. It is increased 2.9

TABLE 42

Average Bi-Parietal Diameter of the Head at Birth

Observer	Average body-length (cm)	Average bi-parietal diameter (cm)
Bonnifay	49.5	9.34
Budin	....	9.50
Bumm	....	9.25
Cadre	48.6	9.26
De Lee	....	9.25
Edgar	....	9.5
Fasbender (males)	48.7	8.76
Fasbender (females)	48.2	8.32
Frankenhäuser (males)	....	8.73
Frankenhäuser (females)	....	8.65
Grillenzoni	....	9.05
Gönner	....	9.25
Hecker	51.2	9.22
Hirst	....	9.25
Hoth (males)	....	9.0
Hoth (females)	....	8.9
Kjölseth	....	9.32
Kultz (males)	....	9.2
Kultz (females)	....	9.1
Lafaille	49.3	9.32
Legou	....	9.50
Liharžik (males)	50.0	10.0
Liharžik (females)	49.0	9.9
Malgaigne	....	9.25
Mandelstam	48.5	7.99
Meigs	....	13.76
Negri (males)	....	9.17
Negri (females)	....	9.38
Popiel	50.5	9.0
Ranke (males)	49.9	9.9
Ranke (females)	48.6	9.4
Schönberg	....	9.0–9.5
Schröder (males)	49.2	9.35
Schröder (females)	48.7	9.22
von Skalkowski	....	9.56
Solares	49.9	9.44
Spiegelberg (males)	50.9	9.35
Spiegelberg (females)	49.3	9.17
Stratz	....	9.25
Tarnier and Chantreuil	....	9.5
Van Pelt	....	9.46
Webster	....	10.0
Weisz	50.0	9.15
Williams	....	9.25
Present series (fresh dead)	50.2	8.8
Present series (unmoulded)	50.2	9.7
Present series (calculated)	50.2	9.7

per cent by injection. Subsequent formalin preservation causes little further increase, the correction figure, after six months' immersion in formalin being −3.1 per cent.

A summary of our findings on this dimension is shown in table 43. The fits of our several expressions to the observations on this dimension are not very satisfactory. The various measurements of the mean deviation of the calculated from the observed values for the 5 cm intervals of crown-rump length, from 5 to 55 cm, inclusive, range

TABLE 43

AURICULO-VERTEX-AURICULAR CIRCUMFERENCE OF HEAD
.4675 CH(MM.)+11.0MM. (351 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Auriculo-Vertex-Auricular Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent				
23-50	36.6	25.1	34	20	27.7	28.1	+ 0.4	+ 1.4	17	5	34.375	—
50-100	75.4	57.0	59	28.5	46.4	46.3	- 0.1	- 0.2	30	10	57.750	68
100-150	123.5	83.9	81	54	69.9	68.7	- 1.2	- 1.7	43	15	81.125	40
150-200	173.2	119.5	103	80	91 5	92.0	+ 0.5	+ 0.5	26	20	104.500	29
200-250	225.0	152.0	133	99	116.5	116.2	- 0.3	- 0.3	50	25	127.875	22
250-300	273.2	184.0	163	122	138.7	138.7	± 0.0	± 0.0	45	30	151.250	18
300-350	324.8	218.5	180	133	163.8	162.8	- 1.0	- 0.6	33	35	174.625	15
350-400	368.3	248.0	199	163	182.2	183.2	+ 1.0	+ 0.5	30	40	198.000	13
400-450	420.0	286.5	215	180	197.6	207.5	+ 9.9	+ 4.8	26	45	221.375	12
450-500	471.4	318.5	253	189	217.5	231.4	+13.9	+ 6.0	24	50	244.750	11
500-544	523.6	358.2	250	213	233.0	255.8	+22.8	+ 9.8	27	55	268.125	10

TABLE 44

AVERAGE AURICULO-VERTEX-AURICULAR CIRCUMFERENCE OF THE HEAD AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE AURICULO-VERTEX-AURICULAR CIRCUMFERENCE (cm)
Bonnifay	49.5	21.31
Clarke	....	18.8
Clarke	....	18.2
Ranke (males)	49.9	19.5
Ranke (females)	48.6	18.5
Present series (calculated)	50.2	24.6

from about 3.5 to 5 mm, and the corresponding mean relative deviations range from about 2.1 to over 3 per cent. Most of the larger deviations occur in the upper third of the distribution and seem due to birth moulding.

We have found no published data on this dimension in the fetus. Joseph Clarke, in 1786, studied an ear-to-ear measurement in the newborn, but his end-points were the anterior superior angles of the ears rather than the external auditory meatus. These values together with those of Bonnifay and of Ranke, for the newborn, are given in table 44.

16. Vertical-Auriculo-Vertex Distance

(Field Graph 13, Tables 45 and 46)

This dimension is the vertical distance from the external auditory meatus to the level of the vertex of the crown. Injection increases this measurement 3.1 per cent, but subsequent preservation in formalin necreases it and the correction figure, after six months' preservation, is -0.4 per cent.

TABLE 45

VERTICAL AURICULO-VERTEX DISTANCE ON HEAD
.175 CH(MM.)+3.5MM. (329 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Vertical Auriculo-Vertex Distance (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean(b)						
Range	Mean		Max.	Min.	Mean(a)		mm.	Per cent		CH Length (cm.)	Value (mm.)	Per cent increment
23-50	35.9	24.3	12	7	9.5	9.8	+0.3	+3.2	16	5	12.25	—
50-100	75.4	57.0	21.5	10	16.7	16.7	±0.0	±0.0	30	10	21.00	71
100-150	123.6	84.0	32	18	25.6	25.1	-0.5	-2.0	43	15	29.75	42
150-200	173.4	119.5	38	28	33.8	33.8	±0.0	±0.0	26	20	38.50	29
200-250	224.5	151.8	51.5	36	43.5	42.8	-0.7	-1.6	49	25	47.25	23
250-300	272.4	182.7	58.5	47	51.5	51.2	-0.3	-0.6	43	30	56.00	19
300-350	325.1	219.0	67	51	60.4	60.4	±0.0	±0.0	33	35	64.75	16
350-400	367.8	247.4	74	62	67.9	67.9	±0.0	±0.0	28	40	73.50	14
400-450	417.5	284.3	81	66	73.2	76.6	+3.4	+4.6	19	45	82.25	12
450-500	473.7	322.0	94	77	81.5	86.4	+4.9	+6.0	19	50	91.00	11
500-544	524.2	357.2	92	79	85.6	95.2	+9.6	+11.2	23	55	99.75	10

The summarized findings for this dimension are given in table 45. The average absolute deviations of the calculated from the observed values for the 5 cm intervals of crown-heel length range from about

1.4 to 1.6 mm. The corresponding relative deviations lie between 2 and 4 per cent. The root mean square deviations range from about 2 to about 3.6 mm. We think the deviations are chiefly the result of birth moulding, although we have no experimental data on this factor.

TABLE 46

Average Vertical-Auriculo-Vertex Distance of the Head at Birth

Observer	Average body-length (cm)	Average vertical-auriculo-vertex distance (cm)
Friedenthal	50.0	8.06
Quetelet (males)	50.0	8.0
Quetelet (females)	49.4	8.0
Present series (calculated)	50.2	9.1

Our findings agree fairly well with the previous observations of Friedenthal on this dimension in the fetus. The values for the newborn are summarized in table 46.

17. Suboccipito-Vertex-Nasion Circumference

(Field Graph 14, Table 47)

This measurement was taken along the sagittal suture from the nasion to the subocciput. It is subject to the errors of determination common to all measurements having the subocciput as an end-point. Injection causes a small increase of 0.9 per cent in this dimension. Subsequent preservation entirely eliminates this change, and no formalin correction is required.

The results obtained from the study of this dimension are summarized in table 47. The calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations of 2.5 to 3.5 mm from the corresponding observed averages. The relative mean deviations range from less than 1 to nearly 2.5 per cent. Practically all of the deviations occur in the last third of the distribution and are probably largely due to birth moulding.

We have found no published records of this dimension in the fetus or newborn. The calculated natal value, as computed by the empirical formula with graphically determined constants (at 50.2 cm crown-heel length) is 24.8 cm.

18. Menton-Bregma Diameter

(Field Graph 15, Table 48)

This measurement was taken from the tip of the chin to the coronal suture, in the midline. The error of determination is considerable in individual cases, but it seems to be largely compensatory. Injection causes an average increase of 4.6 per cent in this diameter. There is little change with subsequent preservation. The formalin correction figure, after six months' immersion, is −4.3 per cent.

TABLE 47

SUBOCCIPITO-VERTEX-NASION CIRCUMFERENCE OF HEAD
.465 CH (MM.) + 15.0 MM. (350 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm.)	Suboccipito-Vertex-Nasion Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm Intervals of Crown Heel Length		
			Observed			(b) Calculated						
Range	Mean		Max	Min	Mean (a)		mm	Per cent.		C H Length (cm)	Value (mm)	Per cent increment
23-50	36.6	25.1	35	22	29.8	32.0	+2.2	+7.4	16	5	38.25	—
50-100	75.4	57.0	60	31	50.4	50.1	-0.3	-0.6	30	10	61.50	61
100-150	123.5	83.9	83	54	72.2	72.4	+0.2	+0.3	43	15	84.75	38
150-200	173.4	119.5	107	83	94.8	95.6	+0.8	+0.8	26	20	108.00	27
200-250	225.0	152.0	146	103	119.2	119.6	+0.4	+0.3	50	25	131.25	22
250-300	273.5	184.2	174	126	142.9	142.2	-0.7	-0.5	44	30	154.50	18
300-350	324.5	218.4	186	150	167.5	165.9	-1.6	-1.0	34	35	177.75	15
350-400	368.3	248.0	203	170	186.3	186.3	±0.0	±0.0	30	40	201.00	13
400-450	420.0	286.5	221	180	205.9	210.3	+4.4	+2.1	26	45	224.25	12
450-500	471.4	318.5	246	195	227.4	234.2	+6.8	+3.0	24	50	247.50	10
500-544	523.6	358.2	260	223	242.5	258.5	+16.0	+6.6	27	55	270.75	9

Table 48 summarizes our observations on this diameter. The absolute deviations of the calculated from the observed values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from 1.6 to 2.6 mm, and the corresponding relative mean deviations range from 2.2 to 4 per cent. They are chiefly in the upper intervals of the progression and probably represent birth moulding.

We found no published data on this diameter in the fetus. Charpentier gives this dimension as 9.0 cm in the newborn. Our value at birth, as computed from the empirical formula with graphically determined constants (at 50.2 cm crown-heel length), is 12.0 cm.

19. Bi-Malar Diameter

(Figure 28, Field Graph 16, Tables 49 and 174)

This dimension is the horizontal distance between the two malar prominences. The mechanical error of determination is small, provided the observer is careful to obtain uniform end-points in each case. Injection causes an increase of 5.7 per cent in this diameter through swelling of the soft tissues over the malar prominences. During subsequent preservation in formalin most of the edema disappears, and after six months the measurement is only 1 per cent greater than in fresh material. We have no check upon the effect of simple formalin preservation or of birth moulding on this dimension, but the type of curve formed by the data, when plotted against the body-length, indicates that these artifacts have no marked effect.

TABLE 48

MENTON BREGMA DIAMETER OF HEAD (HEAD HEIGHT)
.23 CH (MM.)+4.5 MM. (357 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Menton Bregma Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min	Mean (a)		mm.	Per cent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.6	25.1	17	9	12.8	12.9	+0.1	+0.8	17	5	16.0	—
50-100	75.4	57.0	28	15	22.0	21.8	-0.2	-0.9	30	10	27.5	72
100-150	124.2	86.5	39	25.5	33.5	33.1	-0.4	-1.2	46	15	39.0	42
150-200	173.2	119.6	50	39	44.5	44.4	-0.1	-0.2	28	20	50.5	29
200-250	224.9	148.7	65	46	57.4	56.3	-1.1	-1.9	48	25	62.0	23
250-300	273.1	183.9	81	56	68.1	68.3	+0.2	+0.3	46	30	73.5	19
300-350	324.5	218.4	87	71	79.4	80.1	+0.7	+0.9	34	35	85.0	16
350-400	369.1	248.1	96	75	86.3	89.4	+3.1	+3.6	31	40	96.5	14
400-450	420.0	286.5	107	86	96.4	101.1	+4.7	+4.9	26	45	108.0	12
450-500	471.4	318.5	120	94	107.7	112.9	+5.2	+4.8	24	50	119.5	11
500-544	523.6	358.2	124	108	114.9	124.9	+10.0	+8.7	27	55	131.0	10

Table 49 gives our findings for this dimension. The average absolute deviations of our calculated values for the 5 cm intervals of crown-heel length from the corresponding observed means from 5 to 55 cm of body-length, are 1 mm or less in all instances. The relative deviations range from 1.6 to over 4 per cent, being increased by the great relative deviation in the 5 to 10 cm interval of crown-heel length.

Previous observations on this diameter, in the fetal period, have been made by Budin and Ribemont, Retzius, and Sutugin. Our findings are in substantial agreement with those of Retzius but are somewhat higher than those of Budin and Ribemont and of Sutugin.

TABLE 49

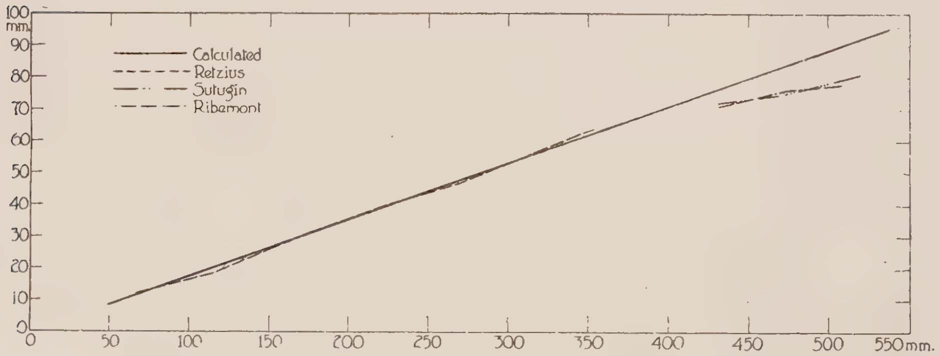
BI-MALAR DIAMETER OF HEAD
.1375 CH(MM.)+0.25MM. (358CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Bi-Malar Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	37.2	31.4	8	4	5.7	5.3	-0.4	-7.0	18	5	7.125	—
50-100	75.4	57.0	12	5	8.9	10.6	+1.7	+19.1	30	10	14.000	96
100-150	123.5	82.0	22	11	15.9	17.2	+1.3	+8.2	44	15	20.875	49
150-200	173.2	119.6	27	18	22.8	24.1	+1.3	+5.7	28	20	27.750	34
200-250	225.0	151.8	37	26.5	30.8	31.2	+0.4	+1.3	50	25	34.625	25
250-300	273.1	183.9	46	30.5	38.3	37.8	-0.5	-1.3	46	30	41.500	20
300-350	324.5	218.4	54	35	46.2	44.9	-1.3	-2.8	34	35	48.375	17
350-400	369.1	248.1	61	43.5	51.6	51.0	-0.6	-1.2	31	40	55.250	14
400-450	420.0	286.5	65	50	57.7	58.0	+0.3	+0.5	26	45	62.125	12
450-500	471.4	318.5	79	57	64.6	65.1	+0.5	+0.8	24	50	69.000	11
500-544	523.6	358.2	86	65	74.3	72.2	-2.1	-2.8	27	55	75.875	10

Our calculated value for this dimension in the newborn, as computed from the empirical formula with graphically established constants (at 50.2 cm crown-heel length) is 6.9 cm.

FIGURE 28

THE GROWTH OF THE BI-MALAR DIAMETER, OR DISTANCE OF THE HEAD, IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Bi-malar distance (diameter of the head) (mm).

20. Bi-Auricular Diameter

(Figure 29, Field Graph 17, Tables 50 and 174)

This measurement was taken as the diameter from one external auditory meatus to the other. Injection increases this diameter in the average by 9.5 per cent, while subsequent immersion in formalin produces a further increase to 12.5 per cent in the first month. After this there is a gradual decrease and the final correction, at six months, is −7.2 per cent.

The progression of this dimension with respect to body-length may be better represented by a shallow parabola with the concavity downward than by a straight line, but no good reason is apparent for this peculiarity. It is possible that a change in type of instrument used and a very slight variation in technique, after a number of the measurements, may be responsible for this difference. The rather large increase due to injection is also not readily explicable, and there is the possibility of some connection between the two phenomena.

TABLE 50

BI-AURICULAR DIAMETER OF HEAD
.16 CH (MM.) + 2.0 MM. (357 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Bi-Auricular Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Percent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.				
23-50	37.2	31.4	10	4	7.7	8.0	+0.3	+3.9	18	5	10.0	—
50-100	75.4	57.0	17	8	13.3	14.1	+0.8	+6.0	30	10	18.0	80
100-150	124.1	84.4	29	17	22.8	21.9	−0.9	−3.9	44	15	26.0	44
150-200	173.2	119.6	34.5	25	30.6	29.7	−0.9	−2.9	28	20	34.0	31
200-250	225.0	152.0	45.5	34.5	39.7	38.0	−1.7	−4.3	50	25	42.0	24
250-300	273.1	183.9	54	40.5	46.6	45.7	−0.9	−1.9	46	30	50.0	19
300-350	324.5	218.4	63	48	54.1	54.9	+0.8	+1.5	34	35	58.0	16
350-400	368.3	248.0	67	52	60.1	60.9	+0.8	+1.3	30	40	66.0	14
400-450	420.0	286.5	72	54	65.4	69.2	+3.8	+5.8	26	45	74.0	12
450-500	471.4	318.5	91	62	73.8	77.4	+3.6	+4.9	24	50	82.0	11
500-544	523.6	358.2	91	77	81.8	85.6	+4.0	+4.9	27	55	90.0	10

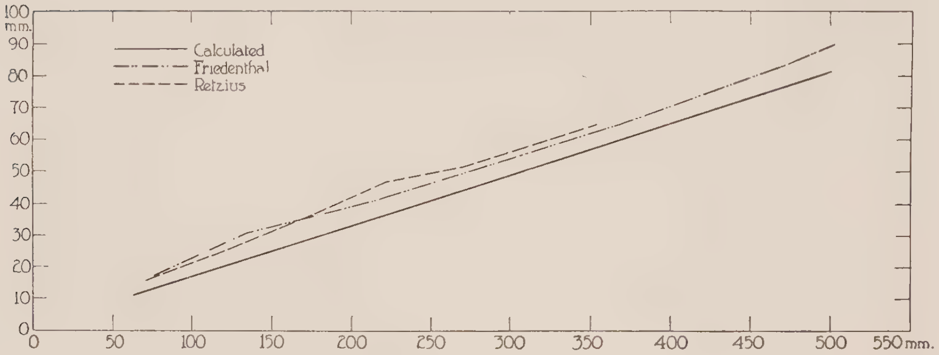
Table 50 summarizes our findings for this dimension. The calculated values, as determined by various empirical formulae, for 5 cm intervals of crown-heel length, show average absolute deviations of

1.1 to 1.8 mm, and average relative deviations of 0.3 to 4.6 per cent, from the corresponding observed means.

Previous observations of this diameter have been made by Friedenthal and Retzius, whose values run consistently higher than ours throughout the entire series. Friedenthal obtained a natal value of 9.05 cm at 50 cm crown-heel length, while our calculated value for the newborn (as computed from the empirical formula, with graphically determined constants) at 50.2 cm crown-heel length is but 8.2 cm.

FIGURE 29

The Growth of the Bi-Auricular Diameter of the Head in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Bi-auricular diameter of the head (mm).

21. Auriculo-Vertex Diameter

(Field Graph 18, Table 51)

This diameter was taken as the diagonal distance, in the transverse plane, from the external auditory meatus to the sagittal suture. This diameter was taken as the average of the two sides. Although the two observations were not recorded separately, no consistent difference was noted between them. Injection increases this distance about 1.6 per cent, while subsequent immersion diminishes it, and at the end of six months' preservation the correction is only −0.5 per cent.

Table 51 summarizes our findings for this dimension. The calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average deviations ranging from 1.3 to 1.9 mm, and average relative deviations of 2.0 to 3 per cent, from the corresponding observed means. These deviations are almost entirely confined to the latter part of the progression and are probably due mainly to birth moulding. However, since no special study was made of the effects of birth moulding on this diameter, we are unable to state definitely that the error was introduced from this source.

TABLE 51

AURICULO-VERTEX DIAMETER OF HEAD
.1825 CH(MM.)+4.5MM.(353 CASES)

Crown Heel Length (mm.)		Crown Rump Length mm	Auriculo-Vertex Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean(b)						
Range	Mean		Max	Min.	Mean(a)		mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	35.9	24.3	12.5	7	10.7	11.1	+0.4	+3.6	16	5	13.625	—
50-100	75.6	57.1	23	11	18.2	18.3	+0.1	+0.5	29	10	22.750	67
100-150	123.5	83.9	32	20	27.3	27.0	-0.3	-1.1	43	15	31.875	40
150-200	173.2	119.6	42	31	36.0	36.1	+0.1	+0.3	28	20	41.000	29
200-250	225.0	151.8	53	40	45.7	45.6	+0.1	+0.2	50	25	50.125	22
250-300	272.8	183.7	66	42	54.2	54.3	+0.1	+0.2	45	30	59.250	18
300-350	324.5	218.4	70	54.5	63.2	63.7	+0.5	+0.8	34	35	68.375	15
350-400	369.1	248.1	80	65	71.3	71.9	+0.6	+0.8	31	40	77.500	13
400-450	420.1	286.5	84	68	76.9	81.5	+4.3	+5.6	26	45	86.625	12
450-500	471.4	318.5	97	77	86.5	90.5	+4.0	+4.6	24	50	95.750	11
500-544	523.6	358.2	99	84	91.1	100.1	+9.0	+9.9	27	55	104.875	10

We have found no published observations on this dimension in the fetus or newborn. The calculated natal value (at 50.2 cm crown-heel length) is 9.6 cm.

22. Nasion-Menton Distance (Height of Face)

(Figure 30, Field Graph 19, Tables 52 and 174)

The determination of this dimension has the mechanical error characteristic of all measurements involving the chin as an end-point. This error can be partially controlled by proper technique, and seems to be largely compensatory. The height of the face is increased 6.6 per cent by formalin injection. Subsequent immersion in formalin causes a still further increase to 8.1 per cent at three months, but following this there is a gradual decrease. At the end of six months the necessary correction figure is −5.4 per cent.

Table 52 summarizes our findings for this dimension. The calculated values for the 5 cm intervals of crown-heel length, from 5 to

55 cm, inclusive, show average absolute deviations of less than 1 mm and average relative deviations of 2.5 to 3.3 per cent, from the corresponding observed values. These deviations are quite uniformly distributed throughout the progression.

TABLE 52

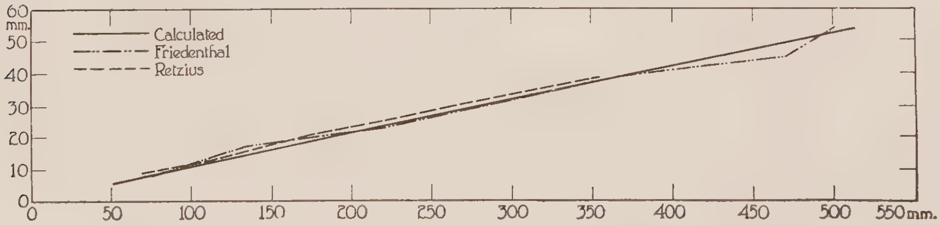
NASION-MENTON DISTANCE ON HEAD
.105 CH (MM.) + 0.5 MM. (349 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Nasion-Menton Distance (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.6	25.1	6	3	4.6	4.3	-0.3	-6.5	16	5	5.75	—
50-100	75.4	57.0	11	5	8.0	8.4	+0.4	+5.0	30	10	11.00	91
100-150	123.6	82.3	18	10	13.1	13.5	+0.4	+3.1	44	15	16.25	48
150-200	173.2	119.6	23	14	18.0	18.6	+0.6	+3.9	28	20	21.50	32
200-250	224.9	148.7	31	19	24.5	24.1	-0.4	-1.6	48	25	26.75	24
250-300	273.1	183.9	32	25	29.8	29.2	-0.6	-2.0	46	30	32.00	20
300-350	324.5	218.4	40	28	34.9	34.6	-0.3	-0.9	34	35	37.25	18
350-400	369.1	248.1	45	31	37.9	39.3	+1.4	+3.7	31	40	42.50	14
400-450	420.0	286.5	56	38	44.2	44.6	+0.4	+0.9	26	45	47.75	12
450-500	471.4	318.5	56	43	50.0	50.0	±0.0	±0.0	24	50	53.00	11
500-544	523.6	358.2	59	48	53.1	55.5	+2.4	+4.5	27	55	58.25	10

Previous observations upon this dimension in the fetal period have been made by Retzius and by Friedenthal. Our findings are in close agreement with the figures recorded by these observers. We have found no published observations on this dimension in the newborn,

FIGURE 30

THE GROWTH OF THE NASION-MENTON DISTANCE OF THE HEAD IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Nasion-menton distance of the head (mm).

aside from a single observation by Friedenthal, who obtained a value of 5.42 cm at 50 cm crown-heel length. Our calculated natal value (computed with the empirical formula with graphically determined constants, at 50.2 crown-heel length) is 5.3 cm.

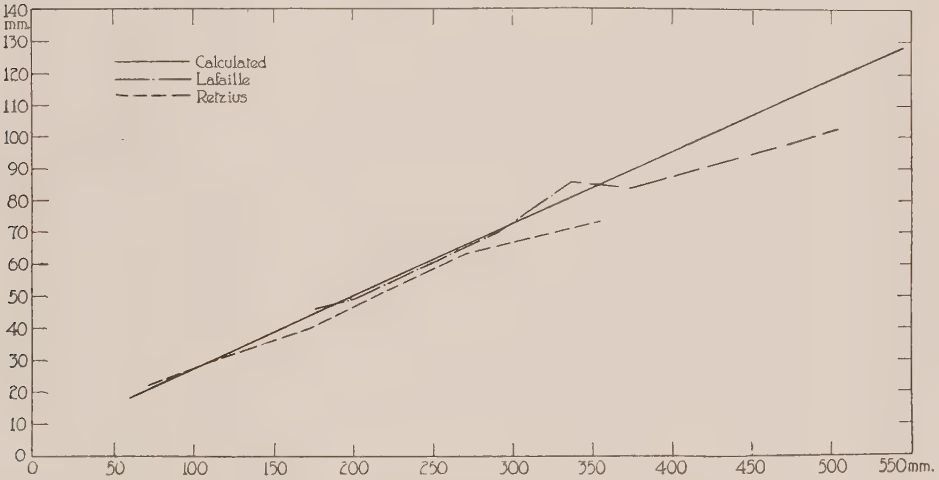
23. Crown-Menton Distance (Vertical Head Height)

(Figure 31, Field Graph 20, Tables 53, 54, and 174)

This measurement was taken vertically from the tip of the chin to the vertex, and may be considered a measure of the height of the head and face. The mechanical errors of determination are not great, although the individual variations are probably increased by the different types of head presentation in the older specimens. Injection produces an increase of 4.6 per cent in this dimension, and the final correction figure, after injection and six months' preservation in 10 per cent formalin, is −4.0 per cent. Birth moulding does not seem to produce any constant change in the averages of the vertical head height, although occasional specimens show marked changes in this diameter as the result of moulding.

FIGURE 31

The Growth of the Vertical Head Height in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Vertical head height (mm).

Our findings in connection with this dimension are given in summary in table 53. The calculated values, as determined by empirical formulae, for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations of about 1 to 1.5 mm, and average relative deviations of about 1 to 3 per cent, from the corresponding observed values. The main deviations lie in the last 5 cm interval, where postmaturity may have a distinct influence.

TABLE 53

CROWN-MENTON DISTANCE ON HEAD (VERTICAL HEAD HEIGHT)
.2275 CH (MM.) + 5.0 MM. (332 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Crown-Menton Distance (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length.		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Percent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.6	25.1	16	9	12.4	13.3	+0.9	+7.3	17	5	16.375	—
50-100	75.4	57.0	26	16	21.7	22.2	+0.5	+2.3	30	10	27.750	69
100-150	123.5	83.7	39	25	32.7	33.3	+0.6	+1.8	42	15	39.125	41
150-200	173.7	119.6	50	39	44.4	44.5	+0.1	+0.2	27	20	50.500	29
200-250	224.9	151.8	67	49	57.3	56.2	-1.1	-1.9	48	25	61.875	23
250-300	272.1	182.5	75	59	67.4	66.9	-0.5	-0.7	44	30	73.250	18
300-350	324.5	218.4	88	70	80.0	78.8	-1.2	-1.5	34	35	84.625	16
350-400	367.8	247.4	97	81	88.5	88.7	+0.2	+0.2	28	40	96.000	13
400-450	417.5	284.3	109	88	99.4	100.0	+0.6	+0.6	19	45	107.375	12
450-500	473.7	321.0	124	105	112.3	112.8	+0.5	+0.4	20	50	118.750	11
500-544	524.3	357.2	130	111	119.2	124.3	+5.1	+4.3	23	55	130.125	10

Previous observations have been made on this dimension in the fetal period by Retzius and by Lafaille. Our findings are in close agreement with their figures, except for the latter part of the dis-

TABLE 54

AVERAGE CROWN-MENTON DISTANCE (VERTICAL HEAD HEIGHT) AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE CROWN-MENTON DISTANCE (cm)
Lafaille	49.7	10.1
Quetelet (males)	50.0	11.1
Quetelet (females)	49.4	11.1
Schadow	46.8	11.7
Present series (calculated)	50.2	11.9

tribution where our values are distinctly higher. Table 54 summarizes the available data on the magnitude of this dimension in the newborn.

24. Orbito-Auricular Distance

(Field Graph 21, Table 55)

This is the distance, in the horizontal plane and a straight line, from the lateral margin of the orbit to the anterior margin of the external auditory meatus. Since both end-points are definite landmarks, the mechanical error of determination of this dimension is very small. Injection produces an increase of 6.5 per cent in this dimension. Subsequent preservation in formalin eliminates the greater part of this enlargement, the formalin correction figure, after six months' immersion following injection, being but −1.7 per cent.

TABLE 55

Orbito-Auriculo Distance of Head
.0775CH(mm.) ± 0.0mm. (360 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Orbito-Auriculo Distance (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent				
23-50	37.2	31.4	4	2	2.7	2.9	+0.2	+7.4	18	5	3.875	—
50-100	75.4	57.0	7.5	3	5.3	5.8	+0.5	+9.4	30	10	7.750	100
100-150	124.2	86.5	13	7	9.9	9.6	-0.3	-3.0	46	15	11.625	50
150-200	173.2	119.6	17	12	13.7	13.4	-0.3	-2.2	28	20	15.500	33
200-250	225.0	152.0	26	12.5	18.1	17.4	-0.7	-3.9	50	25	19.375	25
250-300	273.1	183.9	26	18.5	22.0	21.2	-0.8	-3.6	46	30	23.250	20
300-350	324.5	218.4	31	21	25.7	25.1	-0.6	-2.3	34	35	27.125	17
350-400	369.1	248.1	33.5	24	28.6	28.6	±0.0	±0.0	31	40	31.000	14
400-450	420.0	286.5	36	28	31.8	32.6	+0.8	+2.5	26	45	34.875	12
450-500	471.4	318.5	43	33	36.3	36.5	+0.2	+0.6	24	50	38.750	11
500-544	523.0	358.2	44	34	39.2	40.6	+1.4	+3.6	27	55	42.625	10

Table 55 summarizes our observations on this dimension. The calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show mean deviations of the order of 0.5 mm. The mean relative deviations fall between 3 and 3.6 per cent from the observed means for the corresponding intervals.

We have found no records of previous observations on this dimension in the fetus or newborn. The calculated natal value (at 50.2 cm crown-heel length) is 3.9 cm, as computed from our graphic formula.

25. Orbito-Auriculo-Suboccipital Diameter

(Field Graph 22, Table 56)

This is the distance from the lateral margin of the orbit to the junction of the superior and lateral parts of the occipital bone in the midline. The measurement is subject to some error of determination due to the difficulty in locating accurately the posterior end-point. Injection increases this diameter 8.3 per cent and subsequent preservation in formalin enlarges it still further to 11.5 per cent at the end of the first month. Thereafter there is a gradual reduction, the increase after six months' immersion over the measurement of fresh specimens being 7.7 per cent.

TABLE 56

ORBITO-AURICULO-SUBOCCIPITAL DIAMETER OF HEAD
.1725 CH (MM.) + 2.0 MM. (358 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Orbito-Auriculo-Suboccipital Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	37.2	31.4	13	5	8.8	8.4	-0.4	-4.5	18	5	10.625	—
50-100	75.4	57.0	18	10	14.5	15.0	+0.5	+3.4	30	10	19.250	81
100-150	124.2	86.5	29	18	23.0	23.4	+0.4	+1.7	46	15	27.875	45
150-200	173.2	119.6	37	26	31.7	31.9	+0.2	+0.6	28	20	36.500	31
200-250	225.0	152.0	48	35	41.6	40.8	-0.8	-1.9	50	25	45.125	24
250-300	273.5	184.2	57	42	49.8	49.2	-0.6	-1.2	45	30	53.750	19
300-350	324.5	218.4	66	50	58.4	58.0	-0.4	-0.7	34	35	62.375	16
350-400	369.1	248.1	79	58	65.8	65.7	-0.1	-0.2	31	40	71.000	14
400-450	420.0	286.5	82	64.5	73.3	74.4	+1.1	+1.5	26	45	79.625	12
450-500	471.4	318.5	96	73	83.3	83.3	±0.0	±0.0	24	50	88.250	11
500-544	524.2	329.0	98	85	90.0	92.4	+2.4	+2.7	26	55	96.875	10

Table 56 gives our findings for this dimension. The fits of the calculated values to the corresponding observed averages for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, are very close. The average absolute deviations are less than 0.8 mm in all instances, and the average relative deviations are 2 per cent or less.

There seem to be no published observations on this dimension in the fetus or newborn. Our calculated value for this diameter at birth (estimated by the empirical formula with constants graphically determined, at 50.2 cm crown-heel length) is 8.9 cm.

26. Circumference of Neck

(Field Graph 26, Tables 57 and 58)

This dimension is highly variable, being affected by a number of errors among which the more important are posture, effects of injection, congestion of the larger cervical veins, and, in material from this locality, congenital enlargement of the thyroid gland. Injection causes an average increase of 18.4 per cent in this circumference. Subsequent immersion in formalin raises this increase to about 24 per cent at four months. Thereafter there is a slight decrease to 22 per cent at six months.

TABLE 57

CIRCUMFERENCE OF NECK
33 CH(MM.) + 2.0 MM. (271 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Circumference of Neck (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.6	31.3	21	12.5	16.9	14.1	-2.8	-16.6	11	5	18.5	—
50-100	76.9	57.4	37	19	27.5	27.4	-0.1	-0.4	27	10	35.0	89
100-150	123.1	85.2	48	31	39.9	42.6	+2.7	+6.8	37	15	51.5	47
150-200	164.6	119.7	66	51	58.2	56.3	-1.9	-3.3	18	20	68.0	32
200-250	224.0	151.2	93	63	75.4	75.9	+0.5	+0.7	37	25	84.5	24
250-300	274.3	184.0	107	81	92.9	92.5	-0.4	-0.4	35	30	101.0	20
300-350	326.9	220.2	141	89	109.8	109.8	±0.0	±0.0	29	35	117.5	16
350-400	369.3	248.7	150	94	125.0	123.9	-1.1	-0.9	24	40	134.0	14
400-450	420.5	287.1	174	118	145.2	140.8	-4.4	-3.0	19	45	150.5	12
450-500	476.3	323.6	205	134	172.0	159.2	-12.8	-7.4	13	50	167.0	11
500-544	524.7	361.0	238	161	189.2	175.2	-14.0	-7.4	21	55	183.5	10

TABLE 58

AVERAGE CIRCUMFERENCE OF THE NECK AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE NECK CIRCUMFERENCE (cm)
Lafaille (males)	49.5	20.0
Lafaille (females)	48.2	20.8
Quetelet (males)	50.0	14.8
Quetelet (females)	49.4	14.7
Present series (calculated)	50.2	16.8

Table 57 summarizes our observations on this dimension. The deviations of the calculated from the observed means are not as great as might be expected from the highly variable nature of the material. The calculated values for the 5 cm intervals of crown-heel length, from 10 to 55 cm, inclusive, show average absolute deviations of nearly 3 to over 7 mm from the corresponding observed means. The relative deviations vary from nearly 3 to over 6 per cent. These deviations are most marked in the second, ninth, and tenth 5 cm intervals of crown-heel length.

There seem to be no published observations on the circumference of the neck of the fetus. The natal values for this dimension are summarized in table 58.

TABLE 59

Calculated Values of the External Dimensions of the Head and Neck at Each Five-Centimeter Interval of Crown-Heel Body-Length

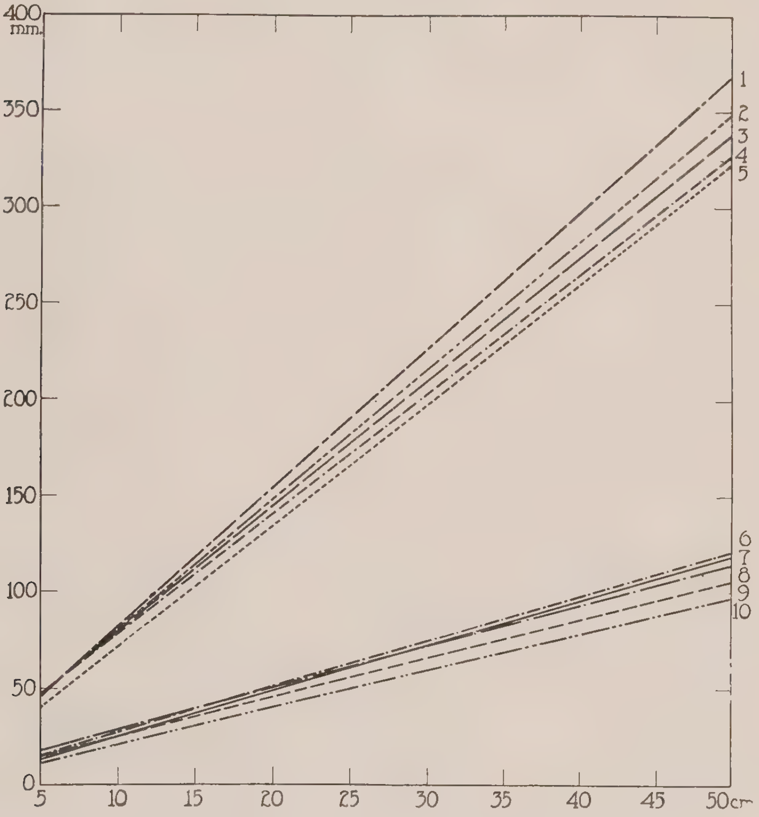
Dimension	Formulae		Calculated values (mm.) at crown-heel lengths of:									
	a	b	5cm.	10cm.	15cm.	20cm.	25cm.	30cm.	35cm.	40cm.	45cm.	50cm.
Occipito-frontal circumference	.675	+13.0	46.8	80.5	114.3	148.0	181.8	215.5	249.3	283.0	316.8	350.5
" " diameter	.235	+ 4.0	15.8	27.5	39.3	51.0	62.8	74.5	86.3	98.0	109.8	121.5
Suboccipito-bregmatic circumference	.625	+16.0	47.3	78.5	109.8	141.0	172.3	203.5	234.8	266.0	297.3	328.5
" " diameter	.2	+ 6.0	16.0	26.0	36.0	46.0	56.0	66.0	76.0	86.0	96.0	106.0
Suboccipito-frontal circumference	.65	+15.0	47.5	80.0	112.5	145.0	177.5	210.0	242.5	275.0	307.5	340.0
" " diameter	.215	+ 7.0	17.8	28.5	39.3	50.0	60.8	71.5	82.3	93.0	103.8	114.5
Occipito-mental circumference	.63	+ 9.0	40.5	72.0	103.5	135.0	166.5	198.0	229.5	261.0	292.5	324.0
" " diameter	.235	+ 2.0	13.8	25.5	37.3	49.0	60.8	72.5	84.3	96.0	107.8	119.5
Large circumference (menton-lambda)	.72	+10.0	46.0	82.0	118.0	154.0	190.0	226.0	262.0	298.0	334.0	370.0
Bi-parietal diameter	.19	+ 2.0	11.5	21.0	30.5	40.0	49.5	59.0	68.5	78.0	87.5	97.0
Auriculo-vertex-auricular circumference	.4675	+11.0	34.4	57.8	81.1	104.5	127.9	151.3	174.7	198.0	221.4	244.8
Vertical auriculo-vertex distance	.175	+ 3.5	12.3	21.0	29.8	38.5	47.3	56.0	64.8	73.5	82.3	91.0
Suboccipito-vertex-nasion circumference	.465	+15.0	38.3	61.5	84.8	108.0	131.3	154.5	177.8	201.0	224.3	247.5
Menton-bregma diameter	.23	+4.5	16.0	27.5	39.0	50.5	62.0	73.5	85.0	96.5	108.0	119.5
Bi-malar distance	.1375	+0.25	7.1	14.0	20.9	27.8	34.6	41.5	48.4	55.3	62.1	69.0
Bi-auricular diameter	.16	+ 2.0	10.0	18.0	26.0	34.0	42.0	50.0	58.0	66.0	74.0	82.0
Auriculo-vertex diameter	.1825	+4.5	13.6	22.8	31.9	41.0	50.1	59.3	68.4	77.5	86.6	95.8
Nasion-menton distance	.105	+ 0.5	5.8	11.0	16.3	21.5	26.8	32.0	37.3	42.5	47.8	53.0
Vertical head height	.2275	+ 5.0	16.4	27.8	39.1	50.5	61.9	73.3	84.6	96.0	107.4	118.8
Orbito-auricular distance	.0775	± 0.0	3.9	7.8	11.6	15.5	19.4	23.3	27.1	31.0	34.9	38.8
" " suboccipital diameter	.1725	+ 2.0	10.6	19.3	27.9	36.5	45.1	53.8	62.4	71.0	79.6	88.3
Neck circumference	.33	+ 2.0	18.5	35.0	51.5	68.0	84.5	101.0	117.5	134.0	150.5	167.0

III. Résumé and Discussion of Findings on the External Dimensions of the Head and Neck

The empirical formulae (as determined by graphic methods) for the various circumferences of this portion of the body are all characterized by the fact that the second or *b* constant is positive. The empirical formulae for the diameters and distances of this region are likewise characterized by positive *b* constants with one exception,

FIGURE 32

THE GROWTH OF THE EXTERNAL DIMENSIONS OF THE HEAD (AS DETERMINED BY EMPIRICAL FORMULAE) IN THE FETAL PERIOD WITH RESPECT TO GROWTH IN CROWN-HEEL LENGTH



Abscissa: Crown-heel length (cm). Ordinates: External dimensions of the head and neck (mm).

1. Large circumference of the head
2. Occipito-frontal circumference
3. Suboccipito-frontal circumference
4. Suboccipito-bregmatic circumference
5. Occipito-mental circumference
6. Occipito-frontal diameter
7. Occipito-mental diameter
8. Suboccipito-frontal diameter
9. Suboccipito-bregmatic diameter
10. Bi-parietal diameter

the orbito-auricular distance, whose empirical formula (as determined by graphic methods) has a zero *b* constant.

The computed values for the various measurements of this group at 5 cm intervals of body-length, from 5 to 50 cm, inclusive, are given in table 59, and curves based upon them are shown in figures 32 and 33. The absolute and percentage increments of this group of measurements for each 5 cm interval of crown-heel body-length, from 5 to 55 cm, inclusive, are presented in the special tables for the individual measurements included in the succeeding pages of this section.

Table 60 gives the computed values of these dimensions at the close of each month of the fetal period, from three to ten months, inclusive; and figures 34 and 35 show curves of the growth of these dimensions with respect to time.

TABLE 60

CALCULATED VALUES OF THE EXTERNAL DIMENSIONS OF THE HEAD AND NECK AT THE CLOSE OF EACH MONTH OF THE FETAL PERIOD

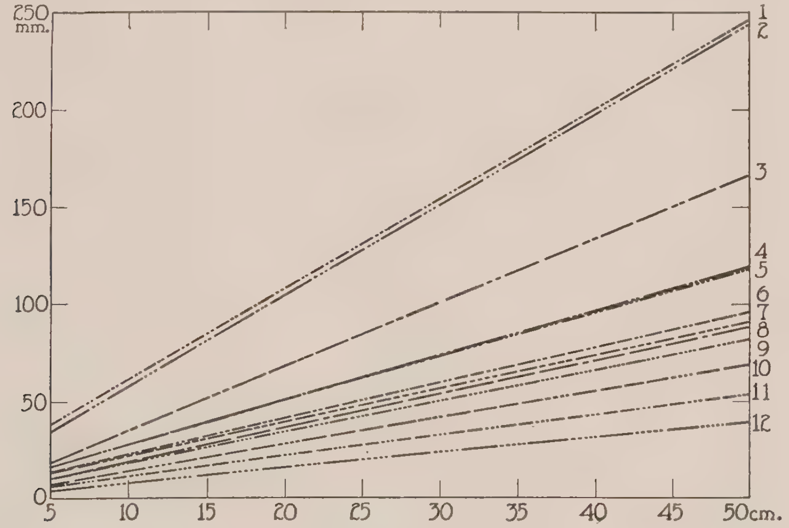
Dimension	Formulae		Calculated values (mm.) at:							
	a	b	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Occipito-frontal circumference	.675	+13.0	60.8	117.9	166.8	210.1	249.6	285.9	319.9	351.9
" " diameter	.235	+4.0	20.6	40.5	57.6	72.6	86.4	99.0	110.9	122.0
Suboccipito-bregmatic circumference	.625	+16.0	60.3	113.1	158.4	198.5	235.1	268.7	300.2	329.8
" " diameter	.2	+6.0	20.2	37.1	51.6	64.4	76.1	86.9	96.9	106.4
Suboccipito-frontal circumference	.65	+15.0	61.0	116.0	163.1	204.8	242.8	277.8	310.6	341.3
" " diameter	.215	+7.0	22.2	40.4	56.0	69.8	82.4	93.9	104.8	114.9
Occipito-mental circumference	.63	+9.0	53.6	106.9	152.6	193.0	229.8	263.7	295.5	325.3
" " diameter	.235	+2.0	18.6	38.5	55.6	70.6	84.4	97.0	108.9	120.0
Large circumference (menton-lambda)	.72	+10.0	61.0	121.9	174.1	220.2	262.4	301.1	337.4	371.4
Bi-parietal diameter	.19	+2.0	15.5	31.5	45.3	57.5	68.6	78.8	88.4	97.4
Auriculo-vertex-auricular circumference	.4675	+11.0	44.1	83.6	117.5	147.5	174.9	200.0	223.6	245.7
Vertical auriculo-vertex distance	.175	+3.5	15.9	30.7	43.4	54.6	64.8	74.3	83.1	91.4
Suboccipito-vertex-nasion circumference	.465	+15.0	47.9	87.3	121.0	150.8	178.0	203.0	226.4	248.4
Menton-bregma diameter	.23	+4.5	20.8	40.2	56.9	71.7	85.1	97.5	109.1	120.0
Bi-malar distance	.1375	+0.25	9.9	21.6	31.6	40.4	48.4	55.8	62.8	69.3
Bi-auricular diameter	.16	+2.0	13.3	26.9	38.5	48.7	58.1	66.7	74.8	82.3
Auriculo-vertex diameter	.1825	+4.5	17.4	32.9	46.1	57.8	68.5	78.3	87.5	96.1
Nasion-menton distance	.105	+0.5	7.9	16.8	24.4	31.2	37.3	43.0	48.2	53.2
Vertical head height	.2275	+5.0	21.1	40.4	56.8	71.4	84.7	97.0	108.4	119.2
Orbito-auricular distance	.0775	±0.0	5.5	12.0	17.7	22.6	27.2	31.3	35.2	38.9
" " suboccipital diameter	.1725	+2.0	14.2	28.8	41.3	52.4	62.5	71.7	80.4	88.6
Neck circumference	.33	+2.0	25.4	53.3	77.2	98.4	117.7	135.4	152.1	167.7

The calculated absolute and percentage increments of the various dimensions of the head and neck in each month of the fetal period are shown in tables 61 and 62. In the fourth month the absolute increments range from 6.5 mm for the orbito-auricular distance, to 60.9 mm for the large (menton-lambda) circumference. Most of the major circumferences of the head make a gain of 40 to 60 mm in this interval. The absolute increments in the sixth month range from 5.0 mm for the orbito-auricular distance, to 46.2 mm for the large circumference. Most of the major circumferences increase between 30 and 45 mm, and most of the major diameters make a gain of between 10 and 15 mm in this month. In the tenth month, the absolute increments range from 3.7 mm for the orbito-auricular distance, to 34.1 mm for the large circumference of the head.

The percentage increments in these dimensions in the fourth fetal month range from 82.0 for the suboccipito-frontal diameter and the

FIGURE 33

A Second Group of Curves Illustrating the Growth of the External Dimensions of the Head and Neck (as Determined by Empirical Formulae) in the Fetal Period with Respect to Growth in Crown-Heel Length



Abscissa: Crown-heel length (cm). Ordinates: External dimensions of the head and neck (mm).

1. Suboccipito-vertex-nasion circumference
2. Auriculo-vertex-auricular circumference
3. Neck circumference
4. Menton-bregma diameter
5. Crown-menton distance (vertical head height)
6. Auriculo-vertex diameter
7. Vertical-auriculo-vertex distance
8. Orbito-auriculo-suboccipital diameter
9. Bi-auricular diameter
10. Bi-malar distance
11. Nasion-menton distance
12. Orbito-auricular distance

suboccipito-vertex-nasion circumference, to 118.2 for the orbito-auricular distance. Six of the twenty-two dimensions increase between 80 and 90 per cent in this month, eight increase between 90 and 100 per cent, and eight increase over 100 per cent, or are more than doubled. By the sixth month the relative increments have undergone a marked decline, the average being a little over 25 per cent and the range from 24.6 per cent for the suboccipito-vertex-nasion circumference, to 28.1 per cent for the orbito-auricular distance. In the seventh month the percentage increments range from 18.0 for the suboccipito-vertex-nasion circumference to 20.0 for the orbito-auricular distance. In the last month of prenatal life all of the dimensions of the head and neck show an increase of about one-tenth, the range being from 9.7 per cent for the suboccipito-vertex-nasion circumference, to 10.4 per cent for the orbito-auricular distance, the nasion-menton distance, and the bi-malar distance or diameter.

TABLE 61

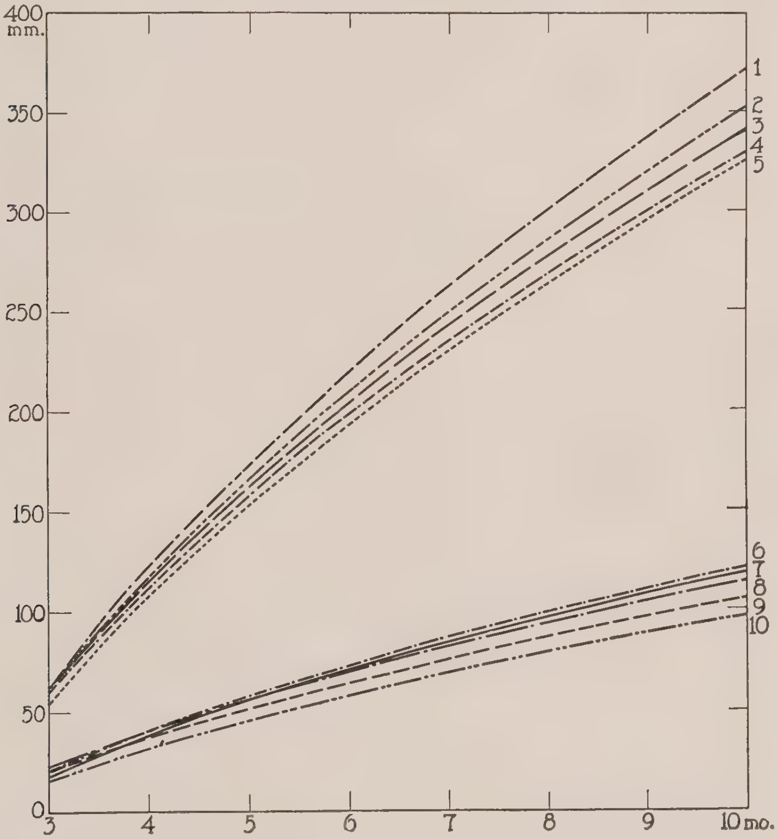
Calculated Absolute Increments of the External Dimensions of the Head and Neck in Each Month of the Fetal Period

Dimension	Absolute increments (mm.) in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Occipito-frontal circumference	57.1	48.9	43.3	39.5	36.3	34.0	32.0
" " diameter	19.9	17.0	15.1	13.7	12.6	11.8	11.1
Suboccipito-bregmatic circumference	52.9	45.3	40.1	36.6	33.6	31.5	29.6
" " diameter	16.9	14.5	12.8	11.7	10.8	10.1	9.5
Suboccipito-frontal circumference	55.0	47.1	41.7	38.0	35.0	32.8	30.7
" " diameter	18.2	15.6	13.8	12.6	11.6	10.8	10.2
Occipito-mental circumference	53.3	45.7	40.4	36.9	33.9	31.8	29.8
" " diameter	19.9	17.0	15.0	13.7	12.6	11.8	11.1
Large circumference (menton-lambda)	60.9	52.2	46.2	42.1	38.7	36.3	34.1
Bi-parietal diameter	16.1	13.8	12.2	11.1	10.2	9.6	9.0
Auriculo-vertex-auricular circumference	39.5	33.9	30.0	27.3	25.2	23.6	22.1
Vertical auriculo-vertex distance	14.8	12.7	11.2	10.2	9.4	8.8	8.3
Suboccipito-vertex-nasion circumference	39.3	33.7	29.8	27.2	25.0	23.4	22.0
Menton-bregma diameter	19.5	16.7	14.7	13.5	12.4	11.6	10.9
Bi-malar distance	11.6	10.0	8.8	8.0	7.4	6.9	6.5
Bi-auricular diameter	13.5	11.6	10.3	9.4	8.6	8.1	7.6
Auriculo-vertex diameter	15.4	13.2	11.7	10.7	9.8	9.2	8.6
Nasion-menton distance	8.9	7.6	6.7	6.1	5.6	5.3	5.0
Vertical head height	19.2	16.5	14.6	13.3	12.2	11.5	10.8
Orbito-auricular distance	6.5	5.6	5.0	4.5	4.2	3.9	3.7
" " suboccipital diameter	14.6	12.5	11.1	10.1	9.3	8.7	8.2
Neck circumference	27.9	23.9	21.2	19.3	17.8	16.6	15.6

The per cents of natal value attained by each dimension at each 5 cm interval of crown-heel length from 5 to 50 cm, inclusive, are shown in table 63. At 5 cm crown-heel length this group of dimensions averages about one-eighth of the natal size, the range being from 10.0 per cent for the orbito-auricular distance, to 15.5 per cent for the suboccipito-vertex-nasion circumference and the suboccipito-frontal diameter. At 25 cm crown-heel length most of the cephalic

FIGURE 34

The Growth of the External Dimensions of the Head (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: External dimensions of the head (mm).

1. Large circumference of the head	6. Occipito-frontal diameter
2. Occipito-frontal circumference	7. Occipito-mental diameter
3. Suboccipito-frontal circumference	8. Suboccipito-frontal diameter
4. Suboccipito-bregmatic circumference	9. Suboccipito-bregmatic diameter
5. Occipito-mental circumference	10. Bi-parietal diameter

and cervical measurements have attained a little over one-half of their natal dimensions, the range being from 50.0 per cent for the orbito-auricular distance, to 53.1 per cent for the suboccipito-vertex-nasion circumference and the suboccipito-frontal diameter. At 45 cm crown-heel length most of these dimensions have completed about nine-tenths of their prenatal growth, the range being from 90.0 for the orbito-auricular distance, to 90.6 for the suboccipito-vertex-nasion circumference and the suboccipito-frontal diameter.

The same values calculated with respect to time are shown in table 64. At three fetal months most of the cephalic and cervical dimensions have attained from one-seventh to one-fifth of their natal size. The range is from 14.1 per cent for the orbito-auricular distance, to 19.3 per cent for the suboccipito-vertex-nasion circumference and suboccipito-frontal diameter. At six months the external dimensions

TABLE 62

Calculated Percentage Increments of the External Dimensions of the Head and Neck in Each Month of the Fetal Period

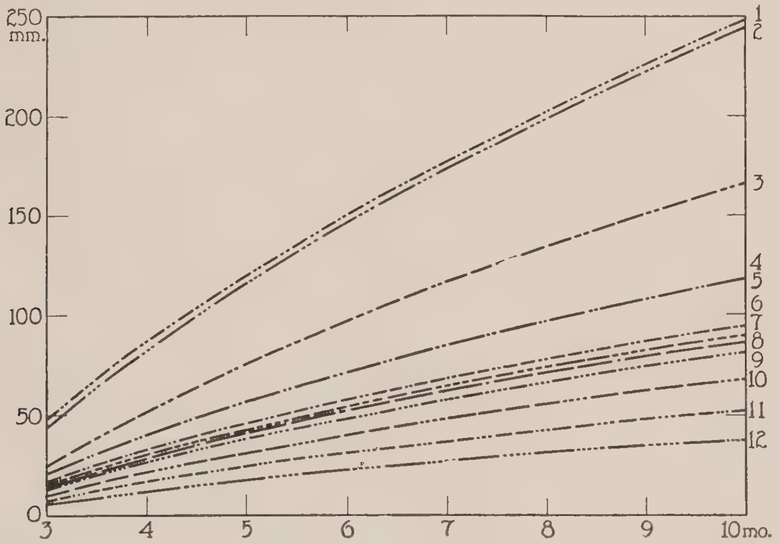
Dimension	Percentage increments in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Occipito-frontal circumference	93.9	41.5	26.0	18.8	14.5	11.9	10.0
" " diameter	96.6	42.0	26.2	18.9	14.6	11.9	10.0
Suboccipito-bregmatic circumference	87.7	40.1	25.3	18.4	14.3	11.7	9.9
" " diameter	83.7	39.1	24.8	18.2	14.2	11.6	9.8
Suboccipito-frontal circumference	90.2	40.6	25.6	18.6	14.4	11.8	9.9
" " diameter	82.0	38.6	24.6	18.1	14.1	11.5	9.7
Occipito-mental circumference	99.4	42.7	26.5	19.1	14.7	12.1	10.1
" " diameter	107.0	44.2	27.0	19.4	14.9	12.2	10.2
Large circumference (menton lambda)	99.8	42.8	26.5	19.1	14.7	12.1	10.1
Bi-parietal diameter	103.9	43.8	26.9	19.3	14.9	12.2	10.2
Auriculo-vertex-auricular circumference	89.6	40.6	25.5	18.5	14.4	11.8	9.9
Vertical auriculo-vertex distance	93.1	41.4	25.8	18.7	14.5	11.8	10.0
Suboccipito-vertex-nasion circumference	82.0	38.6	24.6	18.0	14.0	11.5	9.7
Menton-bregma diameter	93.8	41.5	25.8	18.8	14.6	11.9	10.0
Bi-malar distance	117.2	46.3	27.8	19.8	15.3	12.4	10.4
Bi-auricular diameter	101.5	43.1	26.8	19.3	14.8	12.0	10.2
Auriculo-vertex diameter	88.5	40.1	25.4	18.5	14.3	11.7	9.8
Nasion-menton distance	112.7	45.2	27.5	19.6	15.0	12.3	10.4
Vertical head height	91.0	40.8	25.7	18.6	14.4	11.9	10.0
Orbito-auricular distance	118.2	46.7	28.1	20.0	15.3	12.5	10.4
" " suboccipital diameter	102.8	43.4	26.9	19.3	14.9	12.1	10.2
Neck circumference	109.8	44.8	27.5	19.6	15.1	12.3	10.3

of the head and neck are approximately three-fifths of those of the newborn, ranging from 58.1 per cent for the orbito-auricular distance to 60.7 per cent for the suboccipito-vertex-nasion circumference and the suboccipito-frontal diameter. At nine months all of these values are slightly over nine-tenths those of the fullterm, newborn child, the exact range being from 90.5 per cent for the orbito-auricular distance, to 91.2 per cent for the suboccipito-frontal diameter.

Table 65 shows the computed relative size of the various external dimensions of the head and neck at successive 5 cm intervals of crown-heel length from 5 to 50 cm, inclusive. All of these dimensions show a decrease in relative size in the fetal period with the exception of the orbito-auricular distance which maintains a constant ratio to the crown-heel length. At 5 cm crown-heel length the suboccipito-

FIGURE 35

A Second Group of Curves Illustrating the Growth of the External Dimensions of the Head and Neck (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months(as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: External dimensions of the head and neck (mm).

1. Suboccipito-vertex-nasion circumference
2. Auriculo-vertex-auricular circumference
3. Neck circumference
4. Menton-bregma diameter
5. Crown-menton distance (vertical head height)
6. Auriculo-vertex diameter
7. Vertical-auriculo-vertex distance
8. Orbito-auriculo-suboccipital diameter
9. Bi-auricular diameter
10. Bi-malar distance
11. Nasion-menton distance
12. Orbito-auricular distance

frontal circumference is equal to 95.0 per cent of the total body-length, and the values for the various other dimensions range downward from this figure to 7.8 per cent for the orbito-auricular distance. At 25 cm crown-heel length the large circumference has the largest relative size (76.0 per cent) of any of the dimensions of this group, and the orbito-auricular distance is the smallest (7.8 per cent). At 50 cm the large circumference is equivalent to 74.0 per cent of the body-length and the relative values of the other dimensions range between this figure and 7.8 per cent for the orbito-auricular distance.

TABLE 63

Per Cent of Natal Value Attained by Each External Dimension of the Head and Neck at Each Five-Centimeter Interval of Crown-Heel Length

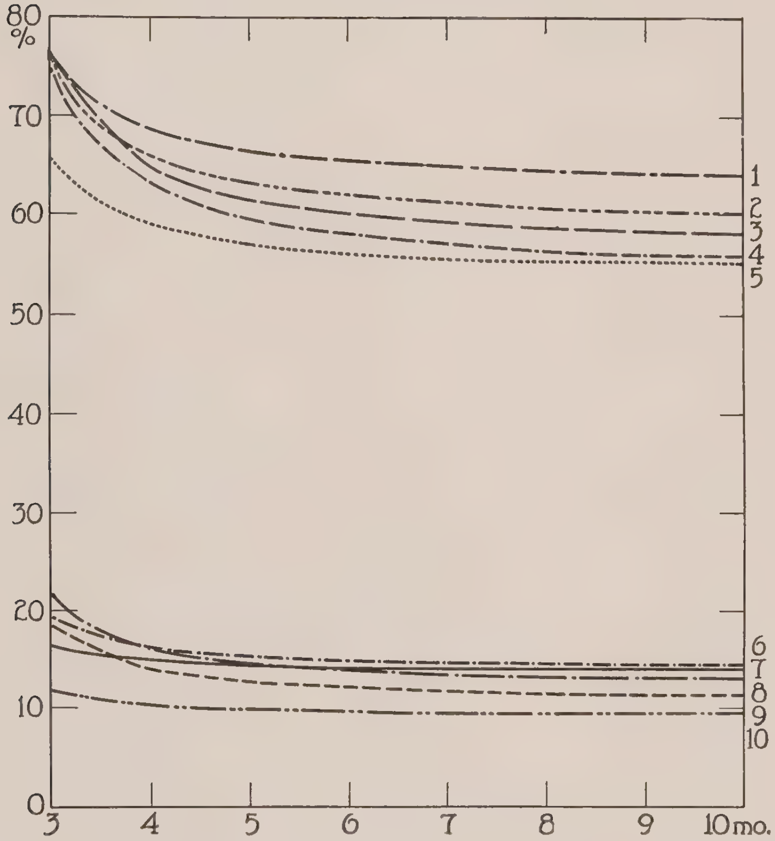
Dimension	Percentage of natal value at crown-heel lengths of:									
	5cm.	10cm.	15cm.	20cm.	25cm.	30cm.	35cm.	40cm.	45cm.	50cm.
Occipito-frontal circumference	13.3	23.0	32.6	42.2	51.9	61.5	71.1	80.7	90.4	100.0
" " diameter	13.0	22.6	32.3	42.0	51.7	61.3	71.0	80.7	90.4	100.0
Suboccipito-bregmatic circumference	14.4	23.9	33.4	42.9	52.5	61.9	71.5	81.0	90.5	100.0
" " diameter	15.1	24.5	34.0	43.4	52.8	62.3	71.7	81.1	90.6	100.0
Suboccipito-frontal circumference	14.0	23.5	33.1	42.6	52.2	61.8	71.3	80.9	90.4	100.0
" " diameter	15.5	24.9	34.3	43.7	53.1	62.4	71.9	81.2	90.7	100.0
Occipito-mental circumference	12.5	22.2	31.9	41.7	51.4	61.1	70.8	80.6	90.3	100.0
" " diameter	11.5	21.3	31.2	41.0	50.9	60.7	70.5	80.3	90.2	100.0
Large circumference (menton-lambda)	12.4	22.2	31.9	41.6	51.4	61.1	70.8	80.5	90.3	100.0
Bi-parietal diameter	11.9	21.6	31.4	41.2	51.0	60.8	70.6	80.4	90.2	100.0
Auriculo-vertex-auricular circumference	14.1	23.6	33.1	42.7	52.2	61.8	71.4	80.9	90.4	100.0
Vertical auriculo-vertex distance	13.5	23.0	32.7	42.3	52.0	61.5	71.2	80.8	90.4	100.0
Suboccipito-vertex nasion circumference	15.5	24.8	34.3	43.6	53.1	62.4	71.8	81.2	90.6	100.0
Menton-bregma diameter	13.4	23.0	32.6	42.3	51.9	61.5	71.1	80.8	90.4	100.0
Bi-malar distance	10.3	20.3	30.3	40.3	50.1	60.1	70.1	80.1	90.0	100.0
Bi-auricular diameter	12.2	22.0	31.7	41.5	51.2	61.0	70.7	80.5	90.2	100.0
Auriculo-vertex diameter	14.2	23.8	33.3	42.8	52.3	61.9	71.4	80.9	90.4	100.0
Nasion-menton distance	10.9	20.8	30.7	40.6	50.5	60.4	70.3	80.2	90.1	100.0
Vertical head height	13.8	23.4	32.9	42.5	52.1	61.7	71.2	80.8	90.4	100.0
Orbito-auricular distance	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
" " suboccipital diameter	12.0	21.9	31.6	41.3	51.1	60.9	70.7	80.4	90.1	100.0
Neck circumference	11.1	21.0	30.8	40.7	50.6	60.5	70.4	80.2	90.1	100.0

The computed relative sizes of these dimensions at the close of each month of the fetal period are shown in table 66. They show the same characteristic changes as those just described and need no special comment. Figures 36 and 37 present curves showing these changes graphically.

The dimensions of most interest in this connection are those representing the vertical growth of the head region. These are vertical head height (crown-menton distance), the nasion-menton distance, and the vertical-auriculo-vertex distance. The computed vertical head height forms approximately one-third (32.8 per cent) of the total body-length at 5 cm crown-heel length, approximately

FIGURE 36

The Changes in the Relative Size of the External Dimensions of the Head in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the external dimensions of the head expressed as per cents of the crown-heel length.

1. Large circumference of the head
2. Occipito-frontal circumference
3. Suboccipito-frontal circumference
4. Suboccipito-bregmatic circumference
5. Occipito-mental circumference
6. Occipito-frontal diameter
7. Occipito-mental diameter
8. Suboccipito-frontal diameter
9. Suboccipito-bregmatic diameter
10. Bi-parietal diameter

one-fourth (24.8 per cent) at 25 cm, and a little less than one-fourth (23.8 per cent) at 50 cm. At three fetal months the vertical head height is 29.8 per cent of the total body-length, at six months, 24.5 per cent, and at birth, 23.7 per cent. The vertical-auriculo-vertex distance shows less change. It is a little less than one-fourth of the body-length (24.6 per cent) at 5 cm crown-heel length, less than one-fifth (18.9 per cent) at 25 cm, and 18.2 per cent at 50 cm, or, considered with respect to time, it is 22.5 per cent at three months, 18.7 per cent at six months, and 18.2 per cent at birth. The computed nasion-menton distance shows still less modification in the fetal period. It forms 11.6 per cent of the body-length at 5 cm crown-heel length and decreases to 10.6 per cent at 50 cm, or considered with respect to time, it is 11.2 per cent at three months, 10.7 per cent at six months, and 10.6 per cent at birth.

TABLE 64

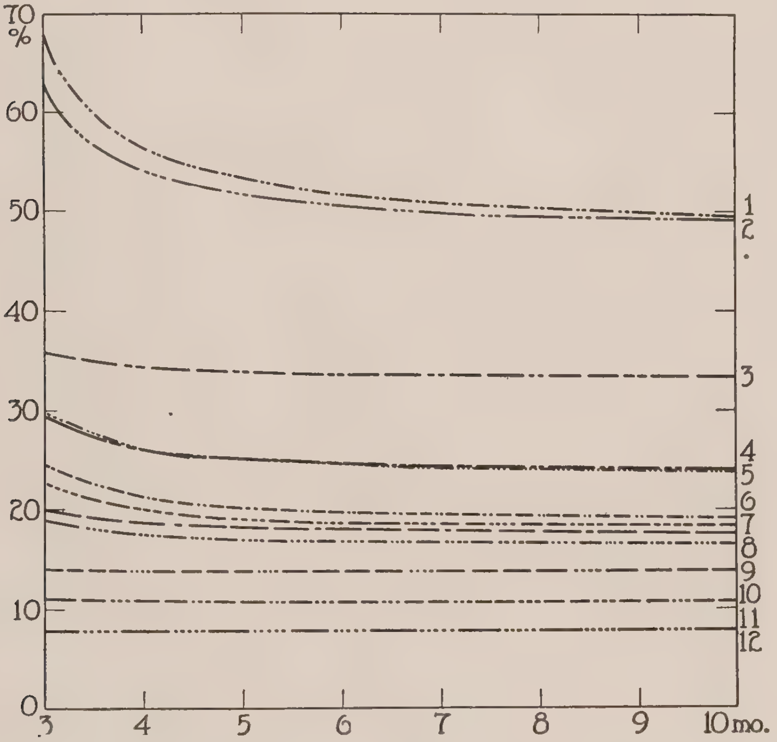
Per Cent of Natal Value Attained by Each External Dimension of the Head and Neck at the Close of Each Month of the Fetal Period

Dimension	Percentage of natal value at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Occipito-frontal circumference	17.3	33.5	47.4	59.7	70.9	81.2	90.9	100.0
" " diameter	16.9	33.2	47.2	59.5	70.8	81.1	90.9	100.0
Suboccipito-bregmatic circumference	18.3	34.3	48.0	60.2	71.3	81.5	91.0	100.0
" " diameter	19.0	34.9	48.5	60.5	71.5	81.7	91.1	100.0
Suboccipito-frontal circumference	17.9	34.0	47.8	60.0	71.1	81.4	91.1	100.0
" " diameter	19.3	35.2	48.8	60.7	71.7	81.7	91.2	100.0
Occipito-mental circumference	16.5	32.9	46.9	59.3	70.6	81.1	90.8	100.0
" " diameter	15.5	32.1	46.3	58.8	70.3	80.8	90.8	100.0
Large circumference (menton-lambda)	16.4	32.8	46.9	59.3	70.7	81.1	90.8	100.0
Bi-parietal diameter	15.9	32.3	46.5	58.8	70.4	80.9	90.8	100.0
Auriculo-vertex-auricular circumference	17.9	34.0	47.8	60.0	71.2	81.4	91.0	100.0
Vertical auriculo-vertex distance	17.2	33.6	47.5	59.7	70.9	81.3	90.9	100.0
Suboccipito-vertex-nasion circumference	19.3	35.1	48.7	60.7	71.7	81.7	91.1	100.0
Menton-bregma diameter	17.3	33.5	47.4	59.8	70.9	81.3	90.9	100.0
Bi-malar distance	14.2	31.2	45.6	58.3	69.8	80.5	90.6	100.0
Bi-auricular diameter	16.2	32.7	46.8	59.2	70.6	81.0	90.9	100.0
Auriculo-vertex diameter	18.1	34.2	48.0	60.2	71.3	81.5	91.1	100.0
Nasion-menton distance	14.8	31.6	45.9	58.6	70.1	80.8	90.6	100.0
Vertical head height	17.7	33.9	47.7	59.9	71.1	81.4	90.9	100.0
Orbito-auricular distance	14.1	30.8	45.5	58.1	69.9	80.5	90.5	100.0
" " suboccipital diameter	16.0	32.5	46.6	59.1	70.5	80.9	90.7	100.0
Neck circumference	15.1	31.8	46.0	58.7	70.2	80.7	90.7	100.0

Some interesting results are obtained by the computation of the absolute and relative head moduli in the fetal period. One of these moduli is computed by adding the transverse arc of the head (auriculo-vertex-auricular circumference) and the occipito-frontal circumference and dividing the result by two. The values obtained in this way are: 40.6 mm at 5 cm crown-heel length, 154.9 mm at

FIGURE 37

A SECOND GROUP OF CURVES ILLUSTRATING THE CHANGES IN THE RELATIVE SIZE OF THE EXTERNAL DIMENSIONS OF THE HEAD AND NECK IN THE FETAL PERIOD



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the external dimensions of the head and neck as per cents of the crown-heel length.

1. Suboccipito-vertex-nasion circumference
2. Auriculo-vertex-auricular circumference
3. Neck circumference
4. Menton-bregma diameter
5. Crown-menton distance (vertical head height)
6. Auriculo-vertex diameter
7. Vertical-auriculo-suboccipital diameter
8. Orbito-auriculo-suboccipital diameter
9. Bi-auricular diameter
10. Bi-malar distance
11. Nasion-menton distance
12. Orbito-auricular distance

25 cm, and 297.7 mm at 50 cm. With respect to time they are, 52.5 mm at three fetal months, 178.8 mm at six months, and 298.8 mm at ten months or birth. This modulus is equivalent to 81.2 per cent of the total body-length at 5 cm crown-heel length, 62.0 per cent at 25 cm, and 59.5 per cent at 50 cm; and to 74.2 per cent at three fetal months, 61.2 at six months, and 59.5 at ten months or birth. The calculated relative values, when computed in terms of the crown-rump length or sitting-height are 106.8 at 5 cm crown-heel length, 91.1 at 25 cm, 88.9 at 50 cm. With respect to time, these calculated relative values are 101.5 at three fetal months, 90.4 at six months, and 88.8 at ten months or birth. The absolute and relative values of this modulus have also been computed by Streeter, who, however, used the sitting-height only in his determinations. At the end of

TABLE 65

RELATIVE SIZE OF THE EXTERNAL DIMENSIONS OF THE HEAD AND NECK (COMPUTED AS PER CENTS OF THE CROWN-HEEL LENGTH) AT EACH FIVE-CENTIMETER INTERVAL OF CROWN-HEEL LENGTH

Dimension	Per cent. of total (crown-heel) length at:									
	5cm.	10cm.	15cm.	20cm.	25cm.	30cm.	35cm.	40cm.	45cm.	50cm.
Occipito-frontal circumference	93.6	80.5	76.2	74.0	72.7	71.8	71.2	70.8	70.4	70.1
" " diameter	31.6	27.5	26.2	25.5	25.1	24.8	24.7	24.5	24.4	24.3
Suboccipito-bregmatic circumference	94.6	78.5	73.2	70.5	68.9	67.8	67.1	66.5	66.1	65.7
" " diameter	32.0	26.0	24.0	23.0	22.4	22.0	21.7	21.5	21.3	21.2
Suboccipito-frontal circumference	95.0	80.0	75.0	72.5	71.0	70.0	69.3	68.8	68.3	68.0
" " diameter	35.6	28.5	26.2	25.0	24.3	23.8	23.5	23.3	23.1	22.9
Occipito-mental circumference	81.0	72.0	69.0	67.5	66.6	66.0	65.6	65.3	65.0	64.8
" " diameter	27.6	25.5	24.9	24.5	24.3	24.2	24.1	24.0	24.0	23.9
Large circumference (menton-lambda)	92.0	82.0	78.7	77.0	76.0	75.3	74.9	74.5	74.2	74.0
Bi-parietal diameter	23.0	21.0	20.3	20.0	19.8	19.7	19.6	19.5	19.4	19.4
Auriculo-vertex-auricular circumference	68.8	57.8	54.1	52.3	51.2	50.4	49.9	49.5	49.2	49.0
Vertical auriculo-vertex distance	24.6	21.0	19.9	19.3	18.9	18.7	18.5	18.4	18.3	18.2
Suboccipito-vertex-nasion circumference	76.6	61.5	56.5	54.0	52.5	51.5	50.8	50.3	49.8	49.5
Menton-bregma diameter	32.0	27.5	26.0	25.3	24.8	24.5	24.3	24.1	24.0	23.9
Bi-malar distance	14.2	14.0	13.9	13.9	13.8	13.8	13.8	13.8	13.8	13.8
Bi-auricular diameter	20.0	18.0	17.3	17.0	16.8	16.7	16.6	16.5	16.4	16.4
Auriculo-vertex diameter	27.2	22.8	21.3	20.5	20.0	19.8	19.5	19.4	19.2	19.2
Nasion-menton distance	11.6	11.0	10.9	10.8	10.7	10.7	10.7	10.6	10.6	10.6
Vertical head height	32.8	27.8	26.1	25.3	24.8	24.4	24.2	24.0	23.9	23.8
Orbito-auricular distance	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
" " suboccipital diameter	21.2	19.3	18.6	18.3	18.0	17.9	17.8	17.8	17.7	17.7
Neck circumference	37.0	35.0	34.3	34.0	33.8	33.7	33.6	33.5	33.4	33.4

the twelfth week Streeter obtained an average absolute modulus of 59 mm, with a minimum value of 56.2 and a maximum value of 62 mm and a percentage modulus of 96.7. Our computed absolute modulus at three fetal months is 52.5 mm and the percentage modulus is 101.5. At the end of the twenty-fourth week Streeter's average absolute modulus is 189 mm, with a minimum of 180 and a maximum of 199 mm, and his percentage modulus is 90.8. Our computed figures at this age (six fetal months) are 178.8 mm and 90.4 per cent, respectively. At the close of the fortieth week Streeter's average absolute modulus is 301 and his percentage modulus is 82.1. Our computed values at this stage are 298.8 mm and 88.8 per cent. These figures show the same general tendency, although our absolute figures are somewhat below Streeter's throughout the series while our relative

TABLE 66

Relative Size of the External Dimensions of the Head and Neck (Computed as Per Cents of the Crown-Heel Length) at the Close of Each Month of the Fetal Period

Dimension	Per cent. of total (crown-heel) length at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Occipito-frontal circumference	85.9	75.9	73.2	72.0	71.2	70.7	70.4	70.1
" " diameter	29.1	26.1	25.3	24.9	24.7	24.5	24.4	24.3
Suboccipito-bregmatic circumference	85.2	72.8	69.5	68.0	67.1	66.5	66.0	65.7
" " diameter	28.5	23.9	22.6	22.1	21.7	21.5	21.3	21.2
Suboccipito-frontal circumference	86.2	74.6	71.6	70.1	69.3	68.7	68.3	68.0
" " diameter	31.4	26.0	24.6	23.9	23.5	23.2	23.0	22.5
Occipito-mental circumference	75.7	68.8	67.0	66.1	65.6	65.2	65.0	64.8
" " diameter	26.3	24.8	24.4	24.2	24.1	24.0	23.9	23.9
Large circumference (menton-lambda)	86.2	78.4	76.4	75.4	74.9	74.5	74.2	74.0
Bi-parietal diameter	21.9	20.3	19.9	19.7	19.6	19.5	19.4	19.4
Auriculo-vertex-auricular circumference	62.3	53.8	51.6	50.5	49.9	49.5	49.2	48.9
Vertical auriculo-vertex distance	22.5	19.8	19.0	18.7	18.5	18.4	18.3	18.2
Suboccipito-vertex-nasion circumference	67.8	56.2	53.1	51.6	50.8	50.2	49.8	49.5
Menton-bregma diameter	29.4	25.9	25.0	24.6	24.3	24.1	24.0	23.9
Bi-malar distance	14.0	13.9	13.9	13.8	13.8	13.8	13.8	13.8
Bi-auricular diameter	18.9	17.3	16.9	16.7	16.6	16.5	16.5	16.4
Auriculo-vertex diameter	24.6	21.2	20.2	19.8	19.5	19.4	19.2	19.1
Nasion-menton distance	11.2	10.8	10.7	10.7	10.6	10.6	10.6	10.6
Vertical head height	29.8	26.0	24.9	24.5	24.2	24.0	23.8	23.7
Orbito-auricular distance	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
" " suboccipital diameter	20.1	18.5	18.1	17.9	17.8	17.7	17.7	17.6
Neck circumference	35.9	34.3	33.9	33.7	33.6	33.5	33.5	33.4

values are somewhat greater in the first and the last part of the fetal period. Considering, however, the radical difference in the methods used in computing these figures, the possible technical divergencies in obtaining the measurements, the racial differences in the material, and the fact that we have made corrections for our formalin artifacts and natal head moulding, the agreement between the two series of figures is a rather striking one.

We have also computed a second cephalic modulus by adding the occipito-frontal diameter to the bi-parietal diameter and the vertical-auriculo-vertex distance and dividing the result by three. The values thus obtained are: 14.6 mm at 5 cm crown-heel length, 58.1 mm at 25 cm, and 112.4 mm at 50 cm; and, with respect to age, 19.1 mm at three fetal months, 67.2 mm at six months, and 112.9 mm at ten months or birth. The relative values of this modulus computed in terms of the crown-heel body-length are: 29.2 per cent at 5 cm crown-heel length, 23.2 per cent at 25 cm, and 22.5 per cent at 50 cm; and with respect to time: 27.0 per cent at three months, 23.0 per cent at six months, and 22.5 per cent at ten months or birth.

Schultz has computed a somewhat similar cephalic modulus adding the greatest length, the greatest width, and the height of the head, and dividing the total of these measurements by three. From this he has computed an index by dividing the values by the trunk length and multiplying the result by 100. We have computed similar figures from our calculated values and find this index to be 89.7 per cent at three months, 80.7 per cent at six months, and 71.5 per cent at ten months or birth. Schultz found this index to average 95 in fetuses of nine weeks and to decrease throughout growth, reaching 57 at birth. Our figures agree with his in their general trend although we find less change than he noted. As in the case of Streeter's figures, it is possible that this divergence is due to a number of factors such as racial differences in material, differences in methods of making measurements and estimating corrections for formalin artifacts, and the like.

The changes in relative proportions of the cranial part of the head may be followed by certain simple indices. Using our computed values as determined from the formulae established by graphic methods, we find the cephalic index is 72.8 at 5 cm crown-heel length, 78.8 at 25 cm, and 79.8 at 50 cm; or, 75.2 at three fetal months, 79.2 at six months, and 79.8 at ten months. The indices as computed from the values obtained by the method of averages and the method of least squares show still smaller increases in the fetal period. Thus apparently the calvarium is becoming relatively broader in the fetal period, but the increase is so small and the variability in the individual measurements of these two dimensions so great that we regard the finding as inconclusive. The observation is not in agreement with that of Schultz, who found a decided decrease in the index between the third fetal month and birth, although our computed figures and his average ones are approximately the same for the newborn.

The height of the head may be compared with its length by dividing the computed vertical-auriculo-vertex distance by the computed occipito-frontal diameter and multiplying the result by 100. The figures thus obtained are: 77.8 at 5 cm crown-heel length, 75.3 at 25 cm, and 74.9 at 50 cm; or, 77.2 at three fetal months, 75.2 at six months, and 74.9 at ten months. Thus the head is apparently becoming slightly longer in proportion to its height during the fetal period.

Comparing the height of the head with the breadth, by dividing the computed vertical-auriculo-vertex distance by the computed bi-parietal diameter and multiplying the result by 100, the values obtained are: 107.0 at 5 cm crown-heel length, 95.6 at 25 cm, and 93.8 at 50 cm; or, 102.6 at three fetal months, 95.0 at six months, and 93.8 at ten months or birth. Thus apparently the head is becoming broader in proportion to its height in the fetal period.

We have measured relatively few dimensions of the facial region in this study, but we may compare the relation of the face height to face breadth by dividing the computed nasion-menton distance by the computed bi-malar diameter and multiplying the result by 100. The figures thus obtained are: 81.7 at 5 cm crown-heel length, 77.5 at 25 cm, and 76.8 at 50 cm; or, 79.8 at three fetal months, 77.2 at six months, and 76.8 at ten months or birth. These figures indicate that there is a slight increase in the relative breadth of the face in the fetal period.

The orbito-auricular distance, although not a true measure of the depth or antero-posterior diameter of the face, may perhaps be used to obtain a rough approximation of the facial growth in this axis. When this distance is compared with the computed face breadth by dividing it by the computed bi-malar diameter and multiplying the result by 100, we obtain values of 54.9 at 5 cm crown-heel length, 56.1 at 25 cm, and 56.2 at 50 cm; or, 55.6 at three fetal months, 55.9 at six months, and 56.1 at ten months or birth.

When the depth of the face is compared with its length by dividing the orbito-auricular distance by the nasion-menton distance and multiplying the result by 100 the following indices are obtained: 67.2 at 5 cm crown-heel length, 72.4 at 25 cm, and 73.2 at 50 cm; and, 69.6 at three fetal months, 72.4 at six months, and 73.1 at ten months or birth. These figures indicate that the face is growing slightly more rapidly in the antero-posterior direction than in the transverse, and distinctly more rapidly in the antero-posterior axis than in the cranio-caudal.

Certain indices may also be used for the purpose of estimating the proportionate growth of the cranial and the facial portions of the head region. The growth in the cranio-caudal direction may be estimated by comparing the face height with the height of the calvarium, by dividing the computed nasion-menton distance by the computed vertical-auriculo-vertex distance and multiplying the result by 100. The indices obtained are: 47.2 at 5 cm crown-heel length, 56.7 at 25 cm, and 58.2 at 50 cm; and, 49.7 at three fetal months, 57.1 at six months, and 58.2 at ten months or birth. These findings agree very closely with those of Schultz.

A second index that may be used in this comparison is one made by dividing the computed nasion-menton distance by the computed vertical head height (crown-menton distance) and multiplying the result by 100. The figures thus obtained are: 35.4 at 5 cm crown-heel length, 43.3 at 25 cm, and 44.6 at 50 cm; and, 37.4 at three fetal months, 43.7 at six months, and 44.6 at ten months or birth. It will be noted that the nasion-menton distance is forming an increasingly large per cent of the vertical-auriculo-vertex distance and the vertical head height, indicating a more rapid relative growth of the facial than of the cranial or neural part of the head in the fetal period.

We may compare the growth in breadth of the face with the growth in head breadth by dividing the computed bi-malar diameter by the bi-parietal diameter and multiplying the result by 100. This index is 61.7 at 5 cm crown-heel length, 69.9 at 25 cm, and 71.1 at 50 cm; and, 63.9 at three fetal months, 70.3 at six months, and 71.1 at ten months or birth. These figures show that the breadth of the face is increasing relatively more rapidly in the period than is the breadth of the head.

While we have measured no dimensions that give a really satisfactory measure of the antero-posterior growth of the face and head, some idea of the relative changes in this axis may be obtained by dividing the orbito-auricular distance by the orbito-auriculo-suboccipital diameter and multiplying the result by 100. The figures for this index are: 36.8 at 5 cm crown-heel length, 43.0 at 25 cm, and 43.9 at 50 cm; or, with respect to time, 38.7 at three fetal months, 43.1 at six months, and 43.9 at ten months or birth. From these it appears that the growth of the face in the antero-posterior axis in the fetal period is relatively more rapid than that of the head in this axis. Thus all of the comparative figures on the growth of the facial and cephalic portions of the head indicate that the former grows relatively more rapidly than the latter in the fetal period.

PART V

SUMMARY OF FINDINGS ON THE EXTERNAL DIMENSIONS OF THE TRUNK

I. Introductory Note

Twenty-two dimensions of the trunk, exclusive of the pelvis, were measured in this study. Of these 17 were linear dimensions and 5 were circumferences. Seven of the linear dimensions were transverse diameters, 4 were antero-posterior or dorso-ventral diameters, and 6 were cranio-caudal or "vertical" distances. Of the last group only one, the distance from the sternal notch to the pubis, is approximately parallel to the vertical longitudinal axis of the body. The others are cords subtending curving segments of the body that extend antero-posteriorly as well as cranio-caudally.

Two dimensions, the distance from the sternal notch to the pubis and the distance from the sternal notch to the umbilicus, involve both the thorax and the abdomen; 10 are primarily measurements of the thorax; and 10 are measurements of the abdomen proper, the dimensions at the level of the tenth pair of ribs being included in this category.

Three dimensions, the bi-acromial diameter, the bi-deltoid circumference, and the bi-deltoid diameter, include a part of the thorax and a portion of the upper extremity, but since the thorax contributes the greater part to their makeup, and they show the same type of growth as other dimensions of the trunk, we include them with the trunk measurements.

II. Consideration of Individual Dimensions*

27. Bi-Acromial Diameter

(Figure 38, Field Graph 27, Tables 67, 68, and 175)

This measurement was taken as a straight line in the transverse plane between the most lateral points of the acromial eminences. The measurement is a fairly constant one, the chief source of error lying in the anterior rotation of the shoulders which sometimes occurs in the delivery of large infants. The dimension requires little or no correction for formalin fixation or injection.

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* The plan used in preparing the following summaries is described in Part I, Section IV (p. 54) of this monograph.

TABLE 67

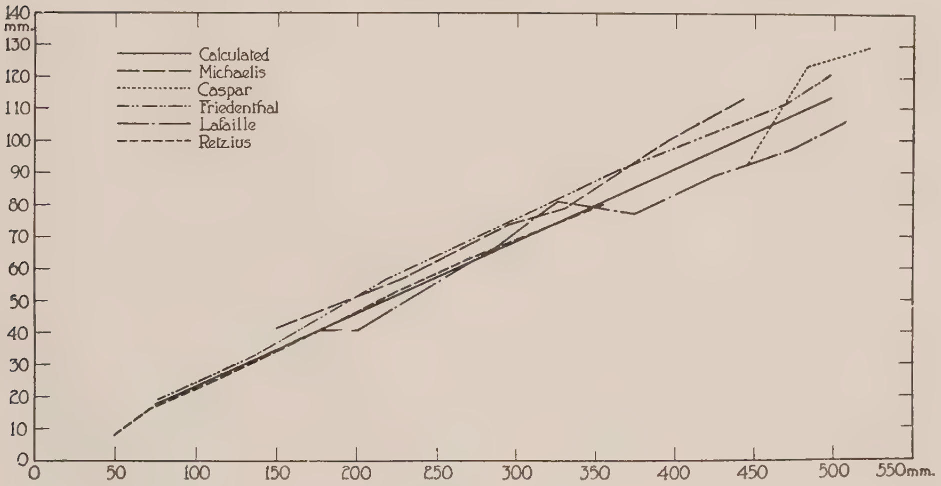
BI-ACROMIAL DIAMETER OF TRUNK
.225 CH (MM.) ± 0.0 MM. (278 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Bi-Acromial Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		C H Length (cm.)	Value (mm.)	Per cent. increment
23 - 50	37.0	31.6	14	6	9.2	8.3	- 0.9	-9.8	13	5	11.25	—
50 - 100	76.0	57.4	22	10.5	17.2	17.1	- 0.1	-0.6	25	10	22.50	100
100 - 150	122.8	87.9	35	20	28.0	27.6	- 0.4	- 1.4	41	15	33.75	50
150 - 200	172.4	119.7	46	31	39.2	38.8	- 0.4	- 1.0	19	20	45.00	33
200 - 250	223.9	151.2	59	42	51.1	50.4	- 0.7	- 1.4	38	25	56.25	25
250 - 300	273.6	183.4	71	51	59.0	61.6	+ 2.6	+4.4	34	30	67.50	20
300 - 350	328.7	222.1	85	59	72.3	74.0	+ 1.7	+2.4	27	35	78.75	17
350 - 400	369.3	248.3	90	70	81.5	83.1	+ 1.6	+2.0	24	40	90.00	14
400 - 450	421.0	287.3	111	83	95.7	94.7	- 1.0	- 1.0	20	45	101.25	12
450 - 500	474.5	321.9	126	94	107.5	106.8	- 0.7	- 0.7	17	50	112.50	11
500 - 544	524.2	361.1	150	116	128.1	117.9	-10.2	- 8.0	20	55	123.75	10

The results obtained from study of this diameter are summarized in table 67. The fit of the straight line curve to these data is a fairly close one. The average absolute deviations for the 5 cm intervals

FIGURE 38

THE GROWTH OF THE BI-ACROMIAL DIAMETER OF THE TRUNK IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Bi-acromial diameter of the trunk (mm).

of crown-heel length are of the order of 2 to 2.4 mm, and the corresponding relative deviations range from about 2.2 to 4.2 per cent. The major part of these deviations fall in the 50 to 55 cm interval of crown-heel length. These high terminal deviations may be due to the effect of birth moulding upon the shoulder girdle.

The growth of the bi-acromial diameter in the fetal period has been previously studied by Caspar, Friedenthal, Lafaille, Michaelis, Retzius, and several other investigators. Our values are lower than those of Michaelis and of Friedenthal, but agree closely with those of Retzius. The values given by Caspar and by Lafaille are quite irregular. Table 68 summarizes the averages for the bi-acromial diameter in the newborn.

TABLE 68

Average Bi-Acromial Diameter at Birth

Observer	Average body-length (cm)	Average bi-acromial diameter (cm)
De Lee	....	11.0
Edgar	....	12.0
Hirst	....	12.0
Quetelet (males)	50.0	12.2
Quetelet (females)	49.6	12.1
Taylor (males)	51.2	12.1
Taylor (females)	50.5	11.9
Webster	....	12.0
Weissenberg (males)	50.8	10.7
Weissenberg (females)	50.0	10.4
Present series (calculated)	50.2	11.3

28. Nipple to Nipple Distance

(Field Graph 28, Tables 69, 70, and 176)

The nipple to nipple or intermammary distance is represented by a straight line drawn between the centers of the mammary areolae. This dimension is increased 5.1 per cent by injection. Subsequent preservation in formalin decreases this artifact to +1.2 per cent after six months.

Table 69 summarizes our observations and computations for this dimension. Our calculated values for the means of the 5 cm intervals

TABLE 69

NIPPLE TO NIPPLE DISTANCE
.125 CH (MM.) ± 0.0 MM. (261 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Nipple to Nipple Distance (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.		CH Length (cm)	Value (mm.)	Per cent. increment
23-50	36.3	31.0	5	3	4.4	4.5	+0.1	+2.3	11	5	6.25	—
50-100	74.2	56.3	11	5.5	8.7	9.3	+0.6	+6.9	21	10	12.50	100
100-150	123.8	88.1	19	12	15.5	15.5	±0.0	±0.0	35	15	18.75	50
150-200	172.8	119.8	26	18	21.7	21.6	-0.1	-0.5	18	20	25.00	33
200-250	225.1	151.9	34	20	28.2	28.1	-0.1	-0.4	37	25	31.25	25
250-300	274.0	183.4	40	26	32.7	34.2	+1.5	+4.6	32	30	37.50	20
300-350	327.7	221.2	49	30	39.7	41.0	+1.3	+3.3	29	35	43.75	17
350-400	367.3	247.2	55	39	46.0	45.9	-0.1	-0.2	21	40	50.00	14
400-450	421.0	287.3	63	43	53.1	52.6	-0.5	-0.9	20	45	56.25	12
450-500	474.5	321.9	74	56	63.4	59.3	-4.1	-6.5	17	50	62.50	11
500-544	361.1	361.1	87	63	74.2	65.5	-8.7	-11.7	20	55	68.75	10

of crown-heel length, from 5 to 55 cm, inclusive, show average deviations of 1 to 1.7 mm from the corresponding observed means. The average relative deviations range from 2.4 to 3.5 per cent. The largest deviations are found in the 45 to 50 cm and 50 to 55 cm intervals. While these may be due in part to the effect of injection, it is quite possible that they also represent a change in the position of the mammae due to the secretion of "witch's milk."

The only published observations on the nipple to nipple distance

TABLE 70

AVERAGE NIPPLE TO NIPPLE (BI-MAMMARY) DISTANCE AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE NIPPLE TO NIPPLE DISTANCE (cm)
Daffner (males)	....	8.07
Daffner (females)	....	7.92
Quetelet (males)	50.0	7.00
Quetelet (females)	49.6	7.00
Present series (calculated)	50.2	6.3

seem to be those of Lafaille. His observed values agree very closely with our calculated ones up to 30 cm crown-heel length, but above this they are quite irregular and distinctly higher. Table 70 shows the collected natal values for this dimension.

29. Bi-Deltoid Circumference

(Field Graph 29, Tables 71, 72, and 175)

This measurement represents the perimeter of the body in the transverse plane at the level of the greatest lateral extension of the shoulders. It is increased 9.7 per cent by formalin injection and subsequent immersion in formalin causes a further enlargement to 12.6 per cent after two months. Thereafter there is a slight decline to 10.5 per cent after six months' preservation. There may be some inaccuracy in the determination of this dimension in large infants, due to the compression of the shoulders at birth.

TABLE 71

BI-DELTOID CIRCUMFERENCE OF TRUNK
.6525 CH(MM.)-2.5MM.(273 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Bi-Deltoid Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent		CH Length cm.	Value (mm.)	Per cent increment
23-50	38.4	32.6	38	17	26.1	22.6	-3.5	-13.4	11	5	30.125	—
50-100	77.0	58.0	61	32	48.4	47.7	-0.7	-1.4	24	10	62.750	108
100-150	122.8	87.9	91	58	75.3	77.6	+2.3	+3.1	40	15	95.375	52
150-200	172.6	119.8	127	94	110.3	110.1	-0.2	-0.2	19	20	128.000	34
200-250	223.9	151.2	172	115	141.7	143.6	+1.9	+1.3	38	25	160.625	25
250-300	273.6	183.4	210	150	173.8	176.0	+2.2	+1.3	34	30	193.250	20.
300-350	326.2	222.2	250	178	214.3	212.3	-2.0	-0.9	26	35	225.875	17
350-400	369.3	248.3	261	207	237.4	238.5	+1.1	+0.5	24	40	258.500	14
400-450	421.0	287.3	309	242	279.4	272.2	-7.2	-2.6	20	45	291.125	13
450-500	474.5	321.9	375	279	324.6	307.1	-17.5	-5.4	17	50	323.750	11
500-544	524.2	361.1	440	347	378.4	339.5	-38.9	-10.3	20	55	366.375	10

Table 71 summarizes our findings and computations of this dimension. The average absolute deviations of the calculated from the observed values of this dimension for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 6 to nearly 8 mm. The corresponding relative deviations fall between 3 and 4 per cent.

The only published observations on this dimension in fetal life seem to be those of Spiegelberg for the latter part of the period. Our calculated values indicate the same general course of growth as do his findings but are slightly lower.

TABLE 72

AVERAGE BI-DELTOID CIRCUMFERENCE AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE BI-DELTOID CIRCUMFERENCE (cm)
De Lee	....	34.0
Edgar	....	33.0
Popiel	50.5	35.0
Quetelet (males)	50.0	32.1
Quetelet (females)	49.6	31.7
Spiegelberg (males)	50.9	34.45
Spiegelberg (females)	49.3	33.38
Present series (calculated)	50.2	32.5

Table 72 gives the available averages for the newborn, which we have collected from the literature, and also our calculated natal value as estimated by the empirical formula with graphically determined constants.

30. Bi-Deltoid Diameter

(Field Graph 30, Tables 73 and 175)

This measurement represents the transverse diameter of the body between the greatest lateral extension of the shoulders caused by the deltoid muscles. The dimension is increased 5.7 per cent by injection, and subsequent preservation in formalin raises this value in one month to 7.0 per cent. Thereafter there is a steady decrease, and after six months the measurement is, on the average, 4.1 per cent greater in injected and preserved material than in fresh specimens.

Table 73 gives our summarized observations on this dimension. Considering the fact that this diameter is a soft-part measurement and that it is considerably affected by formalin artifacts, the agreement of our calculated and observed values is quite close. The average absolute deviations of the calculated from the observed values for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from approximately 1.9 to 2.3 mm. The corresponding relative deviations range from about 1.8 to 2.8 per cent.

We have found no published observations on this diameter in the fetal period or in the newborn. Our calculated value for this dimension in the newborn, as estimated by use of the empirical formula with graphically determined constants (at 50.2 cm crown-heel length) is 13.3 cm.

TABLE 73

Bi-Deltoid Diameter of Trunk
.27CH(mm.)-2.5mm.(277 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Bi-Deltoid Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.				
23-50	37.0	31.6	14	6	9.4	7.5	-1.9	-20.2	13	5	11.0	—
50-100	76.0	57.4	24	11.5	18.6	18.0	-0.6	-3.2	25	10	24.5	123
100-150	122.8	87.9	37	21	30.7	30.7	±0.0	±0.0	40	15	38.0	55
150-200	172.4	119.7	50	34	43.4	44.0	+0.6	+1.4	19	20	51.5	36
200-250	223.9	151.2	67	46	57.8	58.0	+0.2	+0.3	38	25	65.0	26
250-300	273.6	183.4	85	60	69.8	71.4	+1.6	+2.3	34	30	78.5	21
300-350	328.7	222.1	102	69	85.4	86.2	+0.8	+0.9	27	35	92.0	17
350-400	369.3	248.3	113	76	96.2	97.2	+1.0	+1.0	24	40	105.5	15
400-450	421.0	287.3	126	96	111.6	111.2	-0.4	-0.4	20	45	119.0	13
450-500	474.5	321.9	151	108	128.8	125.6	-3.2	-2.5	17	50	132.5	11
500-544	524.5	361.1	177	136	153.6	139.0	-14.6	-9.5	20	55	146.0	10

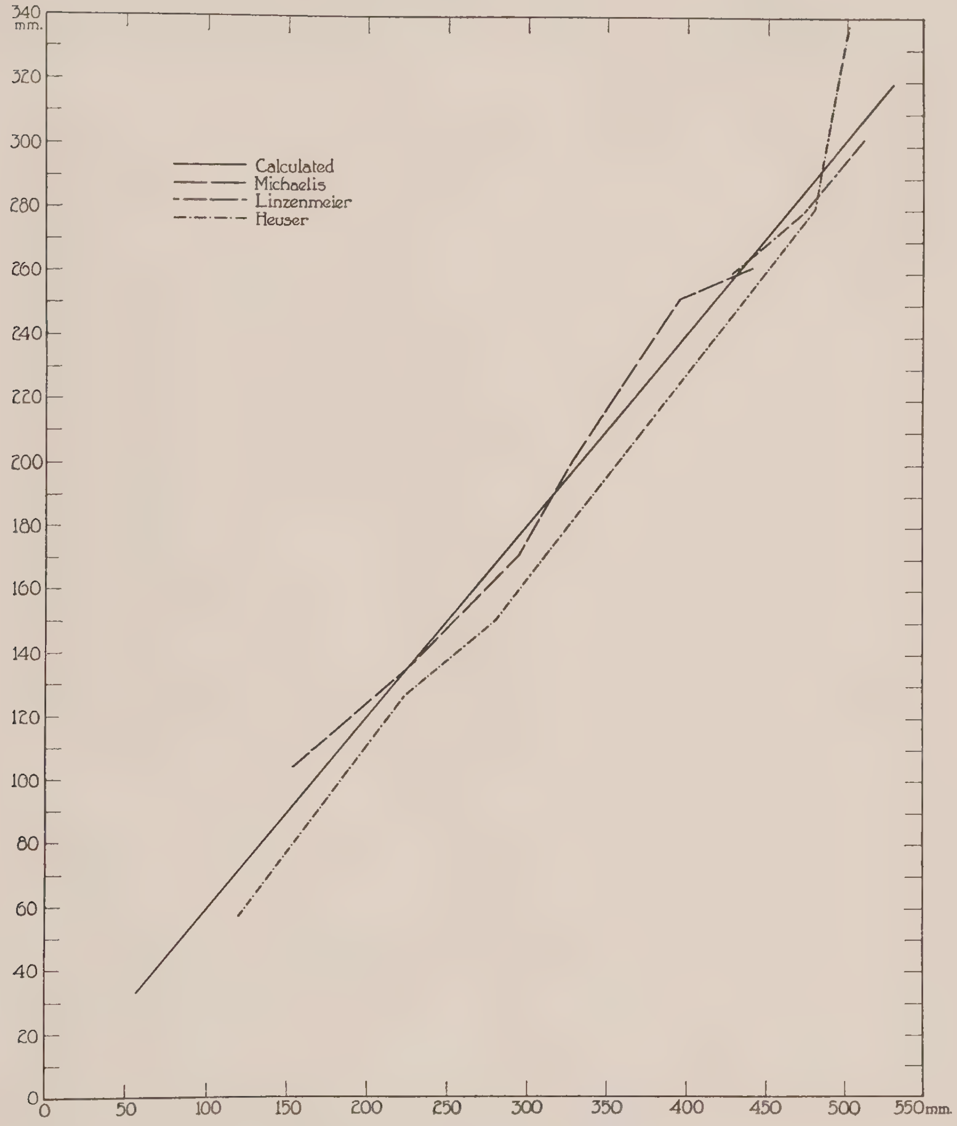
31. Circumference of Thorax at Nipples

(Figure 39, Field Graph 31, Tables 74, 75, and 176)

This dimension was measured with the steel tape in the transverse plane of the body at the level of the nipples. As has been pointed out in Part I, the chest circumference at the nipples undergoes at first a neonatal increase, and, later, a decrease. The latter factor, which was evident in our larger specimens when fresh, is more than counteracted by the effect of injection which increases the circumference 13.5 per cent. Immersion in formalin following injection increases the dimension to 16.3 per cent at the end of two months, but thereafter there is a slow decline, the correction figure at six months being −12.9 per cent.

FIGURE 39

The Growth of the Circumference of the Thorax at the Nipples as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Circumference of the thorax at nipples (mm).

Our summarized findings for this dimension are given in table 74. The average deviations of our calculated values from the corresponding observed means for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, vary from about 3.7 to 4.7 mm, and the corresponding relative deviations are 2 per cent or less. The largest deviations lie in the upper two 5 cm intervals and represent largely our correction for formalin injection and respiratory changes.

TABLE 74

CIRCUMFERENCE OF THORAX AT NIPPLES
.6 CH (MM.) ± 0.0MM. (273 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			(b)						
Range	Mean		Max	Min	Mean (a)	Calculated	mm	Per cent		C H Length (cm)	Value (mm)	Per cent increment
23-50	38.4	32 6	36	18	26.1	23.0	- 3 1	-11.9	11	5	30.0	—
50-100	77 0	58.0	59	32	47 1	46 2	- 0.9	- 1 9	24	10	60 0	100
100-150	123.3	87 9	87	58	72 8	74 0	+ 1.2	+ 1.6	40	15	90.0	50
150-200	172 6	119 8	116	92	1049	1036	- 1.3	- 1 2	19	20	120.0	33
200-250	223.9	151.2	163	118	1369	134 3	- 2.6	- 1.9	38	25	150 0	25
250-300	274 5	183 8	190	143	165 1	164 7	- 0.4	-0 2	34	30	180.0	20
300-350	326.9	220.5	224	170	197.2	196 1	- 1 1	-0.6	28	35	210.0	17
350-400	367 9	248.0	240	198	218.1	220 7	+ 2.6	+1.2	22	40	240.0	14
400-450	421.0	287.3	282	214	252 1	252.6	+ 0 5	+0.2	20	45	270.0	12
450-500	474.5	321 9	340	249	300.2	284.7	-15 5	-5 2	17	50	300.0	11
500-544	524.2	361.6	376	295	334.5	314.5	-20.0	-6.0	20	55	330.0	10

Previous determinations of this dimension in the fetal period have been made by Michaelis, Linzenmeier, Heuser, Schultz, and others. Although the curves plotted from these authors' observations are rather irregular, our calculated curve corresponds fairly closely with their general tendency. The natal circumference of the chest at the nipples has been determined by several authors; some of the more important findings are summarized in table 75.

32. Transverse Diameter of Thorax at Nipples

(Field Graph 32, Tables 76 and 77)

This dimension represents the greatest transverse diameter of the chest in the horizontal plane, at the level of the nipples. The transverse diameter is increased 8 per cent by injection. Subsequent preservation in formalin produces a further increase of about 3 per cent. After six months' immersion the correction figure for formalin preserved material is −9.2 per cent.

TABLE 75

AVERAGE CIRCUMFERENCE OF THE THORAX AT NIPPLES AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE CIRCUMFERENCE OF THORAX AT NIPPLES (cm)
Belot (males—birth)	49.7	33.4
Belot (females—birth)	49.0	31.7
Belot (males—1 day)	49.5	31.8
Belot (females—1 day)	48.0	31.2
Daffner (males)	51.2	30.46–31.53
Daffner (females)	50.3	30.52–31.54
De Lee	....	32.0
Fasbender (males)	48.7	29.90
Fasbender (females)	48.2	30.06
Gundobin (males)	....	32.0
Gundobin (females)	....	31.5
Liharžik (males)	50.0	35.0
Liharžik (females)	49.0	34.0
Linzenmeier (before first inspiration)	51.5	30.5
Linzenmeier (after first inspiration)	51.5	32.3
Orchansky (males)	49.5	33.8
Orchansky (females)	48.3	33.25
Quetelet (males)	50.0	30.2
Quetelet (females)	49.4	29.7
Scammon and Rucker (15 minutes after birth)	....	31.2
Scammon and Rucker (1 day)	....	30.7
Schmid-Monnard (males)	50.6	31.6
Schmid-Monnard (females)	50.1	31.1
Taylor (males)	51.2	32.3
Taylor (females)	50.0	32.1
Webster	....	31.0
Weissenberg (males)	50.8	28.2
Weissenberg (females)	50.0	28.5
Present series (calculated)	50.2	30.1

Our findings regarding this dimension are summarized in table 76. The correspondence between our calculated and observed values

TABLE 76

TRANSVERSE DIAMETER AT NIPPLES
.2025 CH(MM.) ± 0.0MM. (274 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Transverse Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		C H Length (cm)	Value (mm)	Per cent. increment
23-50	37.3	31.9	13.5	5.5	8.3	7.6	-0.7	-8.4	12	5	10.125	—
50-100	77.0	58.0	19	10	15.4	15.6	+0.2	+1.3	24	10	20.250	100
100-150	123.3	87.9	32	19	24.5	25.0	+0.5	+2.0	40	15	30.375	50
150-200	173.2	120.2	41	30	34.7	35.1	+0.4	+1.2	18	20	40.500	33
200-250	224.2	151.4	53	39	46.7	45.4	-1.3	-2.8	39	25	50.625	25
250-300	274.5	183.8	64	49	55.8	55.6	-0.2	-0.4	34	30	60.750	20
300-350	328.0	221.3	75	55	67.0	66.4	-0.6	-0.9	28	35	70.875	17
350-400	367.9	248.0	80	64	73.0	74.5	+1.5	+2.1	22	40	81.000	14
400-450	421.0	287.3	94	72	83.5	85.3	+1.8	+2.2	20	45	91.125	12
450-500	474.5	321.9	111	78	99.7	96.1	-3.6	-3.6	17	50	101.250	11
500-544	524.2	361.1	121	91	108.3	106.2	-2.1	-2.1	20	55	121.375	10

for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, is quite close, the average absolute deviations being less than 1.3 mm in all instances. The corresponding relative deviations are approximately 2 per cent or less.

We have found no published observations upon this dimension

TABLE 77

AVERAGE TRANSVERSE DIAMETER OF THORAX AT NIPPLES AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE TRANSVERSE DIAMETER (cm)
Daffner (males)	....	8.07
Daffner (females)	....	8.08
Gundobin (males)	....	7.7
Gundobin (females)	....	7.6
Liharžik (males)	50.0	11.2
Liharžik (females)	49.0	11.0
Scammon and Rucker (15 minutes after birth)	....	7.7
Scammon and Rucker (3rd day after birth)	....	7.5
Present series (calculated)	50.2	10.2

in the fetal period. The available newborn averages are summarized in table 77.

33. Antero-Posterior Diameter of Thorax at Nipples

(Field Graph 33, Tables 78, 79, and 176)

This measurement represents the greatest diameter in the horizontal plane and the median line, between the anterior and posterior surfaces of the chest, at the level of the nipples. It first undergoes an increase, and then a decrease, in the early part of the neonatal period. The diameter is increased 14.3 per cent by injection. Subsequent preservation in formalin raises its value 15.7 per cent at three months. Thereafter there is a very slight decline, the dimension in preserved material averaging 15.2 per cent greater than that in fresh material.

TABLE 78

ANTERO-POSTERIOR DIAMETER AT NIPPLES
.175 CH (MM.) ± 0.0 MM. (271 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Antero-Posterior Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min	Mean (a)	Mean (b)	mm.	Percent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23- 50	37.3	31.9	10	5	7.2	6.6	-0.6	-8.3	12	5	8.75	—
50-100	77.0	58.0	16	9	12.7	13.5	+0.8	+6.3	24	10	17.50	100
100-150	123.3	87.9	24	16	20.0	21.6	+1.6	+8.0	40	15	26.25	50
150-200	173.2	120.2	35	24	30.2	30.3	+0.1	+0.3	18	20	35.00	33
200-250	223.9	151.2	49	35	40.3	39.2	-1.1	-2.7	38	25	43.75	25
250-300	274.5	183.8	56	40	48.3	48.0	-0.3	-0.6	34	30	52.50	20
300-350	327.7	221.1	65	49	56.7	57.3	+0.6	+1.1	27	35	61.25	17
350-400	367.9	248.0	72	52	62.5	64.4	+1.9	+3.0	22	40	70.00	14
400-450	421.0	287.3	84	59	71.8	73.7	+1.9	+2.6	20	45	78.75	12
450-500	474.5	321.9	98	73	85.5	83.0	-2.5	-2.9	17	50	87.50	11
500-544	524.1	360.8	107	82	94.2	91.7	-2.5	-2.7	19	55	96.25	10

Table 78 summarizes our findings for this diameter. The absolute deviations of the calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, from the corresponding observed means are all less than 2 mm. The corresponding mean relative deviations are all less than 4 per cent.

The growth of this dimension in the fetus has been studied by Michaelis. Our values approximate his findings, although on the whole they are slightly lower. Table 79 summarizes the natal values for this dimension.

TABLE 79

AVERAGE ANTERO-POSTERIOR DIAMETER OF THE THORAX AT NIPPLES AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE ANTERO-POSTERIOR DIAMETER (cm)
Daffner (males)	....	7.83
Daffner (females)	....	7.78
Fasbender (males)	48.7	7.02
Fasbender (females)	48.2	7.08
Gundobin (males)	....	7.70
Gundobin (females)	....	7.5
Scammon and Rucker (15 minutes after birth)	....	8.2
Scammon and Rucker (3rd day after birth)	....	7.6
Present series (calculated)	50.2	8.8

34. Circumference of Thorax at Xiphi-Sternal Junction

(Field Graph 34, Table 80)

This circumference was taken with a steel tape at the level of the xiphi-sternal junction as indicated by the sternal notch. We have no experimental evidence on the effect of respiration on this dimension, but since both the circumference at the nipples and the tenth rib undergo a distinct reduction after birth, the circumference of the xiphi-sternal junction probably follows the same course. This dimension is increased 11.9 per cent by injection. Subsequent preservation in formalin raises this to 13.1 per cent at three months, but thereafter there is a slow reduction to 12.2 per cent at six months.

Table 80 summarizes our findings of this dimension. The fit between our calculated and observed values is not particularly close. The average absolute deviations for the means for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 5 to 10 mm. The average relative deviations for the corresponding values range from about 2.6 to nearly 4 per cent. The greatest deviations fall in the 45 to 55 cm intervals.

TABLE 80

Circumference of Thorax at Xiphi-Sternal Junction
.62CH(mm.)-1.0mm. (225 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Circumference of thorax (mm.)				Difference between (a) and (b)		Numbers of cases	Calculated Values at 5cm. intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	37.5	32.0	42	19	28.7	22.3	- 6.4	-22.6	10	5	30.0	—
50-100	76.9	57.6	58	35	47.4	46.7	- 0.7	- 1.5	19	10	61.0	103
100-150	123.9	88.5	95	63	77.3	75.8	- 1.5	- 1.9	29	15	92.0	51
150-200	172.1	118.6	135	90	109.1	105.7	- 3.4	- 3.1	19	20	123.0	34
200-250	225.0	152.4	164	121	143.2	138.5	-4.7	-3.3	23	25	154.0	25
250-300	272.9	183.8	195	150	170.9	168.2	- 2.7	- 1.6	21	30	185.0	20
300-350	326.8	220.0	230	160	198.4	201.6	+ 3.2	+ 1.6	28	35	216.0	17
350-400	370.0	249.5	247	185	222.7	228.4	+ 5.7	+ 2.6	22	40	247.0	14
400-450	422.6	288.2	290	214	258.9	261.0	+ 2.1	+ 0.8	19	45	278.0	13
450-500	474.6	322.2	341	285	307.6	293.1	-14.5	-4.7	18	50	309.0	11
500-544	525.1	362.9	376	297	339.4	324.6	-14.8	-4.4	17	55	341.0	10

We have found no published records of measurements of this circumference in the fetus or newborn. Our natal value (approximated by use of the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is 31.0 cm.

35. Transverse Diameter of Thorax at Xiphi-Sternal Junction

(Field Graph 36, Table 81)

This dimension represents the greatest breadth of the trunk in the transverse plane at the level of the xiphi-sternal junction. As in the case of the circumference at this level, we have no direct evidence that this diameter is affected by neonatal respiratory changes, but since the chest undergoes a reduction at the nipples and tenth rib, it is probably safe to assume that it also does so at this level. The transverse diameter at the xiphi-sternal junction is increased 4.6 per cent by formalin injection. One month's subsequent immersion in formalin raises this value 4.7 per cent. Thereafter there is a gradual but irregular reduction to 4.0 per cent after six months' preservation.

Table 81 summarizes our findings for this dimension. The deviations between the observed and calculated values for this diameter of the thorax are rather small. The average absolute deviations for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 1 to about 1.4 mm. The corresponding relative deviations range from 1.5 to a little over 2 per cent. The largest deviations are in the last two 5 cm intervals of the progression.

We have found no published observations upon this dimension in the fetus. Zeising states that the transverse diameter of the thorax at the *Herzgrube* is 10.5 cm. Our calculated natal value, as computed from the empirical formula with graphically determined constants (at 50.2 cm crown-heel length), is 10.3 cm.

TABLE 81

TRANSVERSE DIAMETER AT XIPHI-STERNAL JUNCTION
.205 CH (MM.) ± 0.0 MM. (268 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Transverse Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max	Min.	Mean (a)		mm.	Per cent.		C H Length (cm)	Value (mm.)	Per cent. increment
23-50	38.4	32.6	14	6	8.7	7.9	-0.8	-9.2	11	5	10.25	—
50-100	77.4	58.2	19.5	10.5	15.5	15.9	+0.4	+2.6	22	10	20.50	100
100-150	123.3	87.9	30	18	24.5	25.3	+0.8	+3.3	40	15	30.75	50
150-200	173.6	120.4	40	30	34.5	35.6	+1.1	+3.2	17	20	41.00	33
200-250	224.2	151.4	54	40	46.3	46.0	-0.3	-0.6	39	25	51.25	25
250-300	274.5	183.8	64	48	55.8	56.3	+0.5	+0.9	34	30	61.50	20
300-350	328.0	221.3	78	56.5	68.0	67.2	-0.8	-1.2	28	35	71.75	17
350-400	367.3	247.5	83	66	74.6	75.3	+0.7	+0.9	21	40	82.00	14
400-450	421.0	287.3	94	73	84.8	86.3	+1.5	+1.8	20	45	92.25	12
450-500	474.5	321.9	113	81	100.5	97.3	-3.2	-3.2	17	50	102.50	11
500-544	524.1	360.8	123	94	111.6	107.4	-4.2	-3.8	19	55	112.75	10

36. Antero-Posterior Diameter of Thorax at Xiphi-Sternal Junction

(Field Graph 35, Table 82)

This dimension was taken as the greatest distance between the anterior and posterior surfaces of the chest in the midline at the level of the xiphi-sternal junction. Although we have no direct experimental evidence, it seems fairly certain, from observations at the level of the nipples and the tenth rib, that the antero-posterior diameter of the chest at the xiphi-sternal level undergoes first an increase and later a pronounced decrease soon after birth. The antero-posterior diameter of the thorax at the xiphi-sternal junction is increased 13.8 per cent by injection. During subsequent formalin preservation it decreases to 12.8 per cent at six months.

Table 82 summarizes our findings for this dimension. The calculated values for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations of the order of 1.4 to 1.6 mm from the corresponding observed means. The corresponding relative deviations are all less than 3 per cent.

TABLE 82

ANTERO-POSTERIOR DIAMETER AT XIPHI-STERNAL JUNCTION
.18 CH (MM.) ± 0.0MM. (267 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Antero-Posterior Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			(b) Calculated						
Range	Mean		Max.	Min	Mean (a)		mm.	Per cent.		C H Length (cm.)	Value (mm)	Per cent increment
23-50	37.3	31.9	11	6	8.0	5.7	-2.3	-28.7	12	5	9.0	—
50-100	77.4	58.2	17	10	13.5	13.9	+0.4	+3.0	22	10	18.0	100
100-150	123.3	87.9	27	17	21.4	22.2	+0.8	+3.7	40	15	27.0	50
150-200	173.6	120.4	36	28	31.4	31.2	-0.2	-0.6	17	20	36.0	33
200-250	223.9	151.2	49	37	41.7	40.3	-1.4	-3.4	38	25	45.0	25
250-300	274.5	183.8	59	41	50.6	49.4	-1.2	-2.4	34	30	54.0	20
300-350	327.7	221.1	68	48	58.7	59.0	+0.3	+0.5	27	35	63.0	17
350-400	367.3	247.5	75	52	64.4	66.1	+1.7	+2.6	21	40	72.0	14
400-450	421.0	287.3	85	59	74.3	75.8	+1.5	+2.0	20	45	81.0	12
450-500	474.5	321.9	101	75	89.1	85.4	-3.7	-4.2	17	50	90.0	11
500-544	524.1	360.8	111	85	98.2	94.3	-3.9	-4.0	19	55	99.0	10

We have found no published observations on this dimension on the fetus and newborn. Our natal value (estimated by the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is 9.0 cm.

37. Circumference of Abdomen at Tenth Rib

(Field Graph 37, Table 83)

This dimension was taken with a steel tape in the transverse plane of the trunk at the level mentioned. The experimental study of Scammon and Rucker shows that this circumference undergoes a marked reduction in the first day of postnatal life. This dimension is increased 14.4 per cent by injection and during subsequent immersion in formalin undergoes a very slow reduction to 13.9 per cent in six months.

Our observations on this circumference are summarized in table 83.

As in the case with the majority of abdominal dimensions, the deviation of the calculated from the observed values for the circumference of the abdomen at the tenth rib is greater than that of most thoracic measurements. The average absolute deviations of the calculated from the observed values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, vary from nearly 5 to nearly 12 mm, and the corresponding relative deviations from 2 to over 5 per cent. By far the largest deviations are in the 45 to 55 cm intervals, and represent mainly corrections for formalin injection and preservation.

TABLE 83

CIRCUMFERENCE OF ABDOMEN AT TENTH RIB
64 CH (MM.) - 4.0 MM. (216 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Circumference of Abdomen (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.5	31.2	31	19	26.6	19.4	-7.2	-27.1	11	5	28.0	—
50-100	78.2	58.8	57	33	45.3	46.0	+0.7	+1.5	18	10	60.0	114
100-150	123.8	88.3	95	51	74.1	75.2	+1.1	+1.5	28	15	92.0	53
150-200	172.3	118.9	123	94	107.4	106.3	-1.1	-1.0	18	20	124.0	35
200-250	225.0	152.4	166	123	140.8	140.0	-0.8	-0.6	23	25	156.0	26
250-300	272.9	183.8	198	147	168.5	170.7	+2.2	+1.3	21	30	188.0	21
300-350	327.3	220.6	230	173	201.4	205.5	+4.1	+2.0	26	35	220.0	17
350-400	369.2	249.1	247	200	227.8	232.3	+4.5	+2.0	18	40	252.0	15
400-450	423.8	289.3	300	238	266.1	267.2	+1.1	+0.4	18	45	284.0	13
450-500	474.3	322.2	348	287	317.4	299.6	-17.8	-5.6	18	50	316.0	11
500-544	525.1	362.9	395	317	354.2	332.1	-22.1	-6.2	17	55	348.0	10

We have found no published measurements of this dimension in the fetus. Scammon and Rucker found that this circumference averaged 31.4 cm in living infants, fifteen minutes after birth. Our calculated natal value, computed from the empirical formula with the constants graphically determined (at 50.2 cm crown-heel length), is 31.7 cm.

38. Transverse Diameter of Abdomen at Tenth Rib

(Field Graph 38, Tables 84 and 85)

This dimension represents the greatest breadth of the trunk, in the transverse plane, at the level of the tenth rib. The measurement undergoes a slight neonatal reduction. The dimension is slightly increased (2.8 per cent) by injection alone, but during subsequent preservation this artifact drops to 1.4 per cent after six months' immersion in formalin.

TABLE 84

TRANSVERSE DIAMETER AT TENTH RIB
.2075 CH(MM.)-1.0MM. (265 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Transverse Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean(b)						
Range	Mean		Max.	Min.	Mean(a)		mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	37.3	31.9	11	6	8.5	6.8	- 1.7	-20.0	12	5	9.375	—
50-100	77.4	58.2	19	10	15.0	15.1	+0.1	+ 6.7	22	10	19.750	111
100-150	123.4	87.9	29	18	24.2	24.6	+0.4	+ 1.7	39	15	30.125	53
150-200	173.6	120.4	40	30	34.1	35.0	+0.9	+ 2.6	17	20	40.500	34
200-250	223.5	150.9	53	39	45.1	45.4	+0.3	+ 0.7	37	25	50.875	26
250-300	274.5	183.8	65	48	55.4	56.0	+0.6	+ 1.1	34	30	61.250	20
300-350	328.0	221.3	78	58	68.6	67.1	- 1.5	- 2.2	28	35	71.625	17
350-400	367.3	247.5	86	68	75.4	75.2	- 0.2	- 0.3	21	40	82.000	14
400-450	421.1	286.8	99	78	86.7	86.4	- 0.3	- 0.3	19	45	92.375	13
450-500	474.5	321.9	116	83	102.3	97.5	- 4.8	- 4.7	17	50	102.750	11
500-544	524.1	360.8	128	101	116.1	107.8	- 8.3	- 7.1	17	55	113.125	10

Our findings for this diameter are given in a summarized form in table 84. The deviations of the calculated values from the observed means for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, are small. The average absolute deviations are of the order

TABLE 85

AVERAGE TRANSVERSE DIAMETER OF ABDOMEN AT TENTH RIB AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE TRANSVERSE DIAMETER (cm)
Scammon and Rucker (15 minutes after birth)	....	8.9
Scammon and Rucker (3rd day after birth)	....	8.8
Schadow	46.8	10.4
Present series (calculated)	50.2	10.3

of 2 to 2.2 mm. The corresponding relative deviations range from about 1.8 to about 2.6 per cent.

We have found no published observations upon this dimension in the fetus. Table 85 summarizes the natal values of this dimension.

39. Antero-Posterior Diameter of Abdomen at Tenth Rib

(Field Graph 39, Tables 86 and 87)

This dimension represents the greatest antero-posterior diameter of the trunk at the level indicated. The dimension shows a marked neonatal decrease, amounting to at least 8 per cent in the first day. Injection increases the diameter 14.7 per cent. During subsequent immersion in formalin this artifact is decreased to 13.0 per cent in six months.

TABLE 86

ANTERO-POSTERIOR DIAMETER AT TENTH RIB
.1825 CH(MM.)-1.0 MM.(264 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Antero-Posterior Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean(b)						
Range	Mean		Max	Min	Mean(a)		mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent increment
23-50	37.3	31.9	10	6	8.2	5.8	-2.4	-29.3	12	5	8.125	—
50-100	77.4	58.2	16	9	12.6	13.1	+0.5	+4.0	22	10	17.250	112
100-150	123.4	87.9	27	16	20.4	21.5	+1.1	+5.4	39	15	26.375	53
150-200	173.6	120.4	36	26	306	307	+0.1	+0.3	17	20	35.500	35
200-250	223.5	150.9	48	34	40.7	39.8	-0.9	-2.2	37	25	44.625	26
250-300	274.5	183.8	61	39	48.9	491	+0.2	+0.4	34	30	53.750	20
300-350	327.7	221.1	70	47	59.0	588	-0.2	-0.3	27	35	62.875	17
350-400	367.3	247.5	74	54	65.0	660	+1.0	+1.5	21	40	70.000	15
400-450	421.1	286.8	91	59	79.5	759	-3.6	-4.5	19	45	81.125	13
450-500	474.5	321.9	105	77	94.8	856	-9.2	-9.7	17	50	90.250	11
500-544	524.1	360.8	122	88	1064	946	-11.8	-11.1	19	55	99.375	10

Our summarized observations upon this dimension are given in table 86. The fit between the calculated and observed values for this dimension is not so close as that for the transverse diameter at the same level. The several average absolute deviations of the calculated values from the corresponding observed means, for the 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, fall between 2 and 3 mm. The corresponding relative deviations fall between about 3 and 4 per cent.

TABLE 87

AVERAGE ANTERO-POSTERIOR DIAMETER OF THE ABDOMEN AT TENTH RIB AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE ANTERO-POSTERIOR DIAMETER (cm)
Scammon and Rucker (15 minutes after birth)	....	8.5
Scammon and Rucker (3rd day after birth)	....	7.9
Schadow	46.8	9.1
Present series (calculated)	50.2	9.1

We have found no published observations on this dimension in the fetal period. Scammon and Rucker obtained a value of 8.5 cm for living, newborn infants fifteen minutes after birth. Table 87 gives a summary of the values for this dimension in the newborn.

40. Circumference of Abdomen at Umbilicus

(Field Graph 40, Tables 88 and 176)

This circumference was taken with a steel tape at the level of the midpoint of the umbilicus. It is greatly affected by formalin artifacts, undergoing an initial increase of 19.5 per cent with injection. There is little change with subsequent immersion in formalin, the average injection and preservation increment being 19.7 per cent after six months' preservation.

Our findings regarding this dimension are summarized in table 88. The calculated values for the circumference at the umbilicus show average absolute deviations of the order of 9 to 11 mm from the corresponding observed averages for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive. The corresponding relative deviations are of the order of 4 per cent. These high deviations are due largely to corrections for formalin artifacts in the upper two 5 cm intervals of crown-heel length.

The growth of this dimension in the fetal period has been studied by Michaelis. Our calculated values agree closely with his observations. Taylor obtained an average of 26.6 cm for this dimension in living males (at 51.2 cm crown-heel length), and of 25.8 cm for living, newborn females (at 50.0 cm crown-heel length). Our calculated natal value (as estimated by the use of the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is 27.2 cm.

TABLE 88

CIRCUMFERENCE OF ABDOMEN AT UMBILICUS
.5525 CH(MM.) - 5.5 MM. (208 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Circumference of Abdomen (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean(b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent		CH Length (cm.)	Value (mm.)	Per cent. increment
23- 50	36.5	31.2	31	17	22.8	14.7	- 8.1	-33.5	11	5	22.125	—
50-100	77.9	58.5	51	28	38.6	37.5	- 1.1	- 2.8	17	10	49.750	125
100-150	123.8	88.3	80	47	61.6	62.9	+ 1.3	+ 2.1	28	15	77.375	56
150-200	172.3	118.9	105	71	88.3	89.7	+ 1.4	+ 1.6	18	20	105.000	36
200-250	225.1	152.7	142	90	117.5	118.9	+ 1.4	+ 1.2	21	25	132.625	26
250-300	273.5	184.2	180	116	144.8	145.6	+ 0.8	+ 0.6	20	30	160.250	21
300-350	327.6	221.2	212	139	174.5	175.5	+ 1.0	+ 0.6	24	35	187.875	17
350-400	370.2	249.8	230	167	200.4	199.0	- 1.4	- 0.7	17	40	215.500	15
400-450	423.8	289.3	275	194	241.5	228.6	-12.9	- 5.3	18	45	243.125	13
450-500	474.3	322.2	328	268	292.4	256.6	-35.8	-12.2	18	50	270.750	11
500-544	524.4	363.1	367	386	331.0	284.2	-46.8	-14.1	16	55	298.375	10

41. Transverse Diameter of Abdomen at Umbilicus

(Field Graph 41, Table 89)

This dimension represents the greatest breadth of the trunk at the level of the midpoint of the umbilicus. It is increased 3.3 per cent by injection. There is a preliminary decrease of 1.9 per cent during the first month's preservation in formalin, but the value rises to 3.0 per cent after six months' preservation.

Our findings regarding this dimension are summarized in table 89. Considering that this is a soft-part measurement, the fit between our observed means and calculated values is very satisfactory. The average absolute deviations of the values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 2 to 2.2 mm. The corresponding relative deviations range from 2.5 to 3.9 per cent. The largest deviations, both absolute and relative, are in the 45 to 55 cm intervals, and are due partially to correction for formalin artifacts.

We have found no published records of this dimension in the fetus or newborn. Our calculated natal value (estimated by the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is 9.3 cm.

TABLE 89

TRANSVERSE DIAMETER AT UMBILICUS
.19CH(MM.)-2.0MM. (207 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Transverse Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			(b) Calculated						
Range	Mean		Max	Min	Mean (a)		mm.	Per cent.		CH Length (cm)	Value (mm)	Per cent increment
23-50	36.0	31.0	10	5.5	6.9	4.1	-2.8	-40.6	10	5	6.875	—
50-100	77.9	58.5	17	7.5	12.5	12.4	-0.1	-0.8	17	10	16.750	144
100-150	123.0	88.1	29	15	21.1	21.3	+0.2	+0.9	27	15	26.625	59
150-200	172.1	118.6	34	26	29.9	31.0	+1.1	+3.7	19	20	36.500	37
200-250	225.3	152.7	49	32	41.1	41.5	+0.4	+1.0	22	25	46.375	27
250-300	273.5	184.2	60	43	50.7	51.0	+0.3	+0.6	20	30	56.250	21
300-350	327.6	221.2	73	48	60.9	61.7	+0.8	+1.3	24	35	66.125	18
350-400	370.2	249.8	77	57	67.5	70.1	+2.6	+3.9	17	40	76.000	15
400-450	423.8	289.3	91	64	80.3	80.7	+0.4	+0.5	18	45	85.875	13
450-500	474.3	322.2	113	85	97.3	90.7	-6.6	-6.8	18	50	95.750	11
500-544	524.4	362.9	120	92	110.2	100.6	-9.6	-8.7	15	55	105.625	10

42. Antero-Posterior Diameter of Abdomen at Umbilicus

(Field Graph 42, Table 90)

This measurement represents the distance in the median line between the anterior and posterior surfaces of the body at the level of the midpoint of the umbilicus. Injection increases this diameter an average of 20.3 per cent. There is a slight increase during the first month of preservation after injection, but the figure then declines a little to 19.7 per cent at six months.

Table 90 gives a summary of our findings for this diameter. The calculated values for this dimension show average absolute deviations of from 3.7 to over 4 mm from the corresponding observed means for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive. The corresponding relative deviations range between 5 and 6 per cent.

We have found no published observation on this diameter in the fetus or newborn. Our calculated natal value (computed by the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is 8.2 cm.

TABLE 90

ANTERO-POSTERIOR DIAMETER AT UMBILICUS
.165 CH(MM.)-1.0 MM. (208 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Antero-Posterior Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.0	31.0	10	5	6.9	4.9	−1.7	−24.6	10	5	7.25	—
50-100	77.9	58.5	15	8.5	11.6	11.9	+0.3	+2.6	17	10	15.50	114
100-150	123.8	88.3	27	13	18.8	19.4	+0.6	+3.2	28	15	23.75	53
150-200	172.1	118.6	31	19.5	27.5	27.4	−0.1	−0.4	19	20	32.00	35
200-250	225.3	152.7	46	31	36.3	36.2	−0.1	−0.3	22	25	40.25	26
250-300	273.5	184.2	56	33	41.5	44.1	+2.6	+6.3	20	30	48.50	20
300-350	327.6	221.2	64	41	51.9	53.1	+1.2	+2.3	24	35	56.75	17
350-400	370.2	249.8	71	50	62.0	60.1	−1.9	−3.1	17	40	65.00	15
400-450	423.8	289.3	87	60	76.0	68.9	−7.1	−9.3	18	45	73.25	13
450-500	474.3	322.2	97	82	89.8	77.3	−12.5	−13.9	18	50	81.50	11
500-544	524.4	362.9	116	88	101.3	85.5	−15.8	−15.6	15	55	89.75	10

43. Sternal Notch to Pubis

(Figure 40, Field Graph 43, Tables 91, 92, and 175)

This and the following 5 dimensions represent measurements of the trunk between points in the midline of the anterior surface of the body. With a single exception, it has been impossible to express the relation of these dimensions to the crown-heel length by simple straight line formulae; therefore all of the curves have been phased at 25 or 30 cm crown-heel length. In all instances but the present one, each phase has been represented by a straight line. This apparent departure from the simple rectilinear course of growth with respect to total body-length is probably due, in our opinion, to the effects of posture. A further discussion of this factor will be found in connection with the discussion upon correction of preliminary curves in Part I of this publication.

The distance from the sternal notch to the pubis was measured as a straight line in the vertical plane between the base of the sternal notch and the upper margin of the symphysis pubis. This dimension is increased 8.4 per cent by injection, but undergoes a gradual reduction with subsequent preservation in formalin to +7.6 per cent at the close of six months.

TABLE 91

Sternal Notch to Pubis
5 to 30 cm. CH: 0.28 CH (mm.) + 1.5 mm.
30 to 55 cm. CH: 0.4 CH (mm.) $-2\sqrt{\text{CH (mm.)}}$ + 2 mm.
(232 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Sternal Notch to Pubis (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	35.9	30.7	17	7	11.6	11.6	±0.0	±0.0	14	5	15.5	—
50-100	76.6	57.7	29	14	23.6	22.9	-0.7	-3.0	22	10	29.5	90
100-150	123.8	88.4	47	28	36.3	36.2	-0.1	-0.3	28	15	43.5	47
150-200	172.7	119.0	59	39	48.7	49.8	+1.1	+2.3	18	20	57.5	32
200-250	226.2	153.2	78	56	63.5	64.8	+1.3	+2.0	26	25	71.5	25
250-300	273.5	184.2	100	50	79.1	78.1	-1.0	-1.2	20	30	85.5, 85.4	20
300-350	327.2	220.6	115	83	100.0	101.5	+1.5	+1.5	27	35	102.6	20
350-400	371.2	248.6	126	96	116.9	123.1	+6.2	+5.3	23	40	121.0	18
400-450	422.6	288.2	152	106	136.0	135.3	-0.7	-0.5	19	45	137.6	14
450-500	474.6	322.2	169	141	157.3	146.8	-10.5	-6.6	18	50	155.3	13
500-544	525.1	362.9	190	123	179.8	157.0	-22.8	-12.1	17	55	172.1	11

Table 91 gives the summary of our observations on this measurement. The calculated values differ from the corresponding observed means for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, by average absolute deviations of about 4 to 5 mm and by average relative deviations of about 3 to 3.5 per cent. The greatest absolute and percentage deviations are in the 45 to 55 cm intervals. They represent mainly the correction for formalin artifacts.

TABLE 92

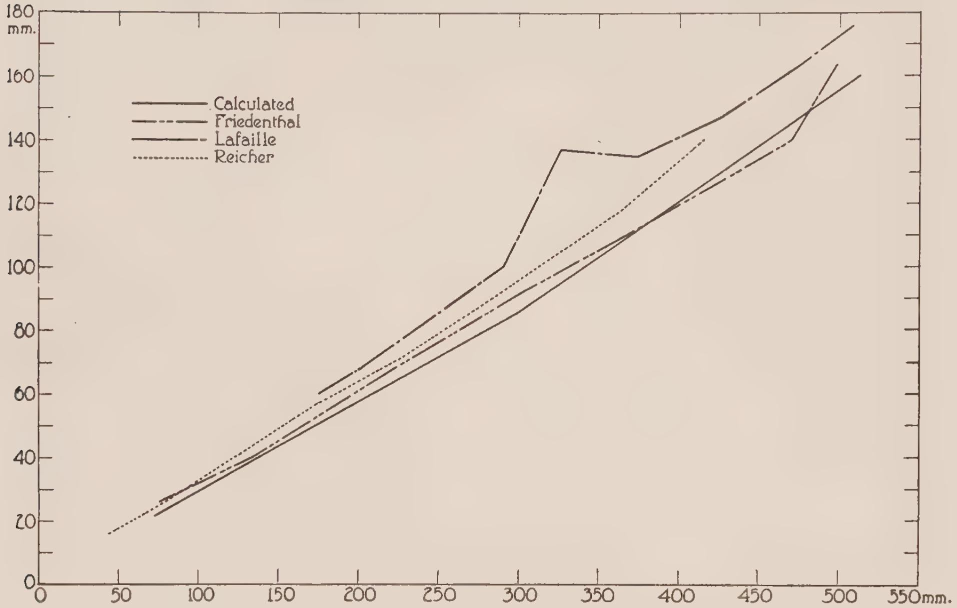
Average Distance from Sternal Notch to Pubis at Birth

Observer	Average body-length (cm)	Average distance sternal notch to pubis (cm)
Friedenthal	50.0	16.42
Reicher (males)	49.4	17.84
Reicher (females)	50.0	17.98
Present series (calculated)	50.2	15.8

This dimension has been studied in the fetal period by Friedenthal, Lafaille, Reicher, and Schultz. The observations of the last two investigators are not recorded with respect to body-length. Lafaille's values are extremely irregular and distinctly higher than our calculated ones. The calculated curve for this measurement is in fairly close agreement with the plotting of Friedenthal's observations, considering the variability of the measurement. The available data on this dimension are summarized in table 92.

FIGURE 40

The Growth of the Distance from the Sternal Notch to the Pubis in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Distance from sternal notch to pubis (mm).

44. Sternal Notch to Umbilicus

(Figure 41, Field Graph 44, Tables 93 and 175)

This dimension represents the distance, in the vertical plane, from the sternal notch to the midpoint of the umbilicus. It is increased 9.4 per cent by injection alone and subsequent preservation in formalin raises this value to 10.4 per cent in two months. Thereafter there is a slow decline to +9.8 per cent in six months.

Table 93 gives the summary of our findings for this measurement. The calculated values for the 5 cm intervals of crown-heel length,

TABLE 93

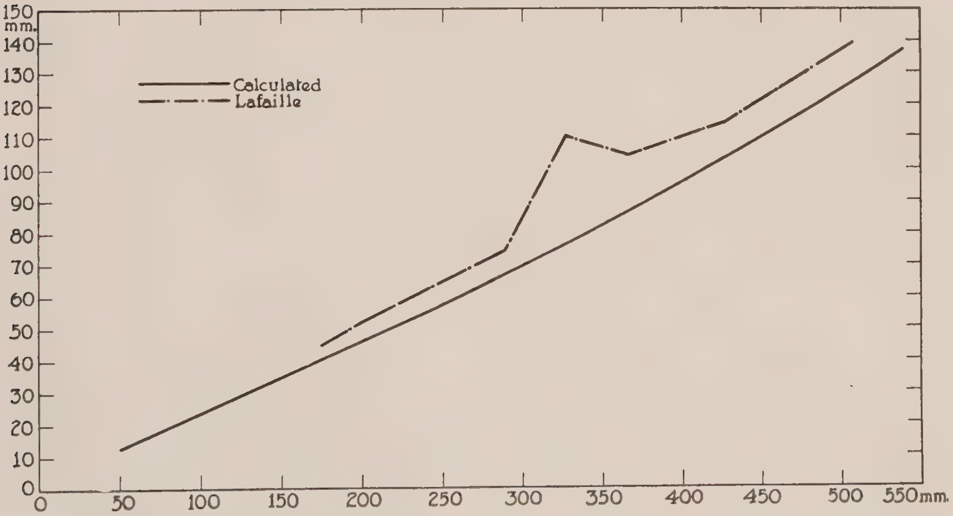
STERNAL NOTCH TO UMBILICUS
5 TO 25 CM. CH: .22 CH (MM.) + 1.5 MM.
25 TO 55 CM. CH: .27 CH (MM.) − 11.0 MM.
(224 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Sternal Notch to Umbilicus (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.		CH Length (cm.)	Value (mm.)	Percent. increment
23-50	36.5	31.4	13	7	9.9	9.8	- 0.1	- 1.0	11	5	12.5	—
50-100	76.6	57.7	25	12	18.6	18.3	- 0.3	- 1.6	21	10	23.5	88
100-150	123.8	88.4	37	22	30.0	30.7	+ 0.7	+ 2.3	28	15	34.5	47
150-200	172.1	118.6	44	34	39.5	39.4	- 0.1	- 0.3	19	20	45.5	32
200-250	225.5	152.9	63	39	51.0	51.1	+ 0.1	+ 0.2	25	25	56.5	24
250-300	273.5	184.2	81	54	63.0	62.8	- 0.2	- 0.3	20	30	70.0	24
300-350	326.8	220.0	94	63	79.0	77.2	- 1.8	- 2.2	27	35	83.5	19
350-400	369.6	248.6	107	72	93.0	87.8	- 5.2	- 5.7	20	40	97.0	16
400-450	422.6	288.2	126	89	110.3	103.1	- 7.2	- 6.5	19	45	110.5	14
450-500	474.3	322.2	138	116	126.5	117.1	- 9.4	- 7.4	18	50	124.0	12
500-544	525.5	362.8	163	130	141.0	130.9	-10.9	- 7.7	16	55	137.5	11

from 5 to 55 cm, inclusive, show average absolute deviations of the order of 2.3 to 3.5 mm, and average relative deviations of 2.5 to 3.6

FIGURE 41

THE GROWTH OF THE DISTANCE FROM THE STERNAL NOTCH TO THE UMBILICUS IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Distance from sternal notch to umbilicus (mm).

per cent, from the corresponding observed means. The greatest of these deviations lie in the upper part of the progression and represent correction for formalin artifacts.

Lafaille seems to be the only observer who has studied the growth of this dimension in the fetus. His observations form an extremely irregular curve when plotted against crown-heel length. Our calculated values show the same tendency of growth as indicated by Lafaille's data but the values above 30 cm crown-heel length are all smaller.

We have found no other published observations on this dimension in the newborn. Our calculated value, by the empirical formula with graphically determined constants (at 50.2 cm crown-heel length), is 12.5 cm.

TABLE 94

STERNAL NOTCH TO XIPHI-STERNAL JUNCTION
.11 CH (MM.) − 1.5 MM. (233 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Sternal Notch to Xiphi-Sternal Junction (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.				
23-50	36.5	31.2	6	1	3.4	2.5	-0.9	-26.5	11	5	4.0	—
50-100	76.6	57.7	12	5	8.1	6.9	-1.2	-14.8	21	10	9.5	138
100-150	123.8	88.4	16	8	11.8	12.1	+0.3	+2.5	30	15	15.0	58
150-200	173.0	119.4	20	12	16.4	17.5	+1.1	+6.7	21	20	20.5	37
200-250	225.5	152.7	27	17	21.9	23.3	+1.4	+6.4	25	25	26.0	27
250-300	273.5	184.2	36	23	29.1	28.6	-0.5	-1.7	20	30	31.5	21
300-350	326.7	220.1	40	29	34.7	34.4	-0.3	-0.9	29	35	37.0	17
350-400	370.0	249.5	46	33	39.3	39.2	-0.1	-0.3	22	40	42.5	15
400-450	422.6	288.2	56	39	45.6	45.0	-0.6	-1.3	19	45	48.0	13
450-500	474.3	322.2	57	48	52.2	50.7	-1.5	-2.9	18	50	53.5	11
500-544	525.1	362.9	66	48	55.9	56.3	+0.4	+0.7	17	55	59.0	10

45. Sternal Notch to Xiphi-Sternal Junction

(Field Graph 45, Table 94)

This dimension was measured as a straight line between the base of the sternal notch and the xiphi-sternal junction. As might be expected, since this is practically a measurement of the length of the sternum, there is no increase in this dimension with injection. Subsequent preservation in formalin, however, causes an average increase of 4.2 per cent in the first month. This rises to 5.1 per cent after four months' preservation, but drops again to 4.1 per cent after six months' preservation.

Table 94 summarizes our observation for this dimension. The fit between our calculated and observed values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, is quite a close one. All of the average absolute deviations are less than 0.8 mm. The relative deviations range between 3.7 and 4 per cent.

We have found no observations upon this dimension in the fetus or newborn. Our calculated natal value (as determined by the empirical formula with constants graphically determined, at 50.2 cm crown-heel length) is 5.4 cm.

TABLE 95

XIPHI-STERNAL JUNCTION TO PUBIS
5 TO 25 CM. CH: .19 CH. (MM.) + 1.5 MM.
25 TO 55 CM. CH: .26 CH. (MM.) - 16.0 MM.
(226 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Xiphi-Sternal Junction to Pubis (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent				
23- 50	36.5	31.2	13	5	8.2	8.4	+0.2	+2.4	11	5	11.0	—
50-100	76.6	57.7	21	9	15.9	16.0	+1.0	+0.6	21	10	20.5	86
100-150	123.8	88.4	36	19	25.9	25.0	-0.9	-3.4	28	15	30.0	46
150-200	172.7	119.0	45	24	32.6	33.3	+0.7	+2.1	18	20	39.5	32
200-250	225.5	152.7	54	37	43.3	44.3	+1.0	+2.3	25	25	49.0	24
250-300	273.5	184.2	72	46	54.3	55.1	+0.8	+1.4	20	30	62.0	26
300-350	327.2	220.6	79	55	68.3	69.0	+0.7	+1.0	27	35	75.0	21
350-400	370.0	249.5	95	64	81.7	80.2	-1.5	-2.1	22	40	88.0	17
400-450	422.6	288.2	106	68	95.9	93.8	-2.1	-2.2	19	45	101.0	15
450-500	474.3	322.2	121	91	110.6	107.3	-3.3	-3.0	18	50	114.0	13
500-544	525.1	362.9	150	123	133.6	130.5	-3.1	-2.3	17	55	127.0	11

46. Xiphi-Sternal Junction to Pubis

(Field Graph 46, Table 95)

This dimension represents the distance, in the vertical plane, from the xiphi-sternal junction to the upper margin of the symphysis pubis. The dimension is increased 11.2 per cent by injection alone, but this value falls to 7.5 per cent after one month's preservation and to 6.6 per cent after six months' preservation.

Table 95 summarizes our observations on this dimension. The distance from the xiphi-sternal junction to the pubis is one of the more constant measurements of this group. The average absolute deviations of the calculated from the corresponding observed values, for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 1.4 to 2.5 mm. The corresponding relative deviations range from about 1.5 to about 3.4 per cent.

We have found no published observations upon this dimension in the fetus or newborn. Our calculated natal value (as estimated by the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is 11.5 cm.

47. Xiphi-Sternal Junction to Umbilicus

(Field Graph 47, Tables 96 and 175)

This measurement represents the distance in a straight line from the xiphi-sternal junction to the midpoint of the umbilicus. The dimension is increased 13.8 per cent by injection, probably mainly by the protrusion of the interior abdominal wall. This value drops to 12.0 per cent after one month's preservation and to 11.0 per cent after six months' preservation in formalin.

TABLE 96

XIPHI-STERNAL JUNCTION TO UMBILICUS
5 TO 25 CM. CH: .125 CH(MM.)+1.75 MM.
25 TO 55 CM. CH: .18 CH(MM.)-12.0 MM.
(223 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Xiphi-Sternal Junction to Umbilicus (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	36.5	31.4	8	4	6.3	6.3	±0.0	±0.0	11	5	8.00	—
50-100	76.6	57.7	16	6	10.8	11.3	+0.5	+4.6	21	10	14.25	78
100-150	123.8	88.4	25	14	18.8	17.2	-1.6	-8.5	28	15	20.50	44
150-200	172.1	118.6	33	16	23.4	23.3	-0.1	-0.4	19	20	26.75	30
200-250	225.5	152.9	42	24	30.5	29.9	-0.6	-1.9	25	25	33.00	23
250-300	273.5	184.2	49	29	36.0	37.2	+1.2	+3.3	20	30	42.0	27
300-350	327.2	220.6	63	33	46.4	46.9	+0.5	+1.1	27	35	51.0	21
350-400	369.6	248.6	68	42	55.4	54.5	-0.9	-1.8	20	40	60.0	18
400-450	423.8	289.3	78	47	66.4	64.3	-2.1	-3.0	18	45	69.0	15
450-500	474.3	322.2	69	70	76.6	73.4	-3.2	-4.2	18	50	78.0	13
500-544	525.5	362.8	105	82	89.8	82.6	-7.2	-8.0	16	55	87.0	12

Table 96 summarizes our findings for this dimension. The values obtained by computation from the empirical formula for this dimension show average absolute deviations ranging from about 1.2 to 1.8 mm and average relative deviations of from 3.2 to 3.8 per cent of the corresponding observed averages for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive.

Retzius has made measurements of this dimension in fetuses between 7 and 35 cm crown-heel length. While his measurements show the same general course of growth as do our calculated values they are slightly above ours in all instances. We have found no published observations upon this dimension in the newborn. Our calculated natal value, as computed from the empirical formula with constants determined by graphic methods (at 50.2 cm crown-heel length), is 7.8 cm.

TABLE 97

UMBILICUS TO PUBIS
5 TO 25 cm. CH: .072 CH (MM.) − 0.5 MM.
25 TO 55 cm. CH: .09 CH (MM.) − 5.0 MM.
(225 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Umbilicus to Pubis (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.				
23-50	36.5	31.2	4	1	2.1	2.1	±0.0	±0.0	11	5	3.1	—
50-100	76.6	57.7	8	3	5.3	5.0	-0.3	-5.7	21	10	6.7	114
100-150	123.8	88.4	12	5	8.2	8.4	+0.2	+2.9	28	15	10.3	54
150-200	172.7	119.0	15	7	10.4	11.9	+1.5	+14.4	18	20	13.9	35
200-250	225.5	152.9	19	10	14.6	15.7	+1.1	+7.1	25	25	17.5	26
250-300	273.5	184.2	28	14	20.0	19.6	-0.4	-2.0	20	30	22.0	26
300-350	327.2	220.6	29	15	24.3	24.4	-0.1	-0.4	27	35	26.5	20
350-400	369.6	248.6	42	25	31.2	28.3	-2.9	-10.4	22	40	31.0	17
400-450	423.8	289.3	45	24	34.8	33.1	-1.7	-5.1	18	45	35.5	15
450-500	474.3	322.2	49	32	40.1	37.7	-2.4	-6.4	18	50	40.0	13
500-544	525.1	362.9	62	42	51.4	42.3	-9.1	-21.5	17	55	44.5	11

48. Umbilicus to Pubis

(Field Graph 48, Tables 97 and 175)

This dimension was defined as the shortest distance in a straight line from the midpoint of the umbilicus to the upper margin of the pubis. It is increased 14.7 per cent by injection alone, but there is a marked decline during subsequent preservation in formalin, the value falling to 8.9 per cent in the first month and to 7.0 per cent at the close of six months.

A summary of our observations is given in table 97. The calculated values for this dimension show average absolute deviations of approximately 1 to 2 mm and average relative deviations of about 3.5 to 7 per cent from the corresponding observed means for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive. These deviations are irregularly scattered along the entire course of the progression.

Measurements on this dimension on fetuses from 7 to 35 cm crown-heel length have been published by Retzius. Our calculated values show a fairly close fit with his observed ones. We have found no published observations on this dimension in the newborn. Our calculated natal value, as computed by the empirical formula with graphically determined constants (at 50.2 cm crown-heel length) is 4.0 cm.

III. Résumé and Discussion of the Findings on the External Dimensions of the Trunk

Of the 22 formulae developed by graphic methods for computing the relations of the external dimensions of the trunk to the total or

TABLE 98

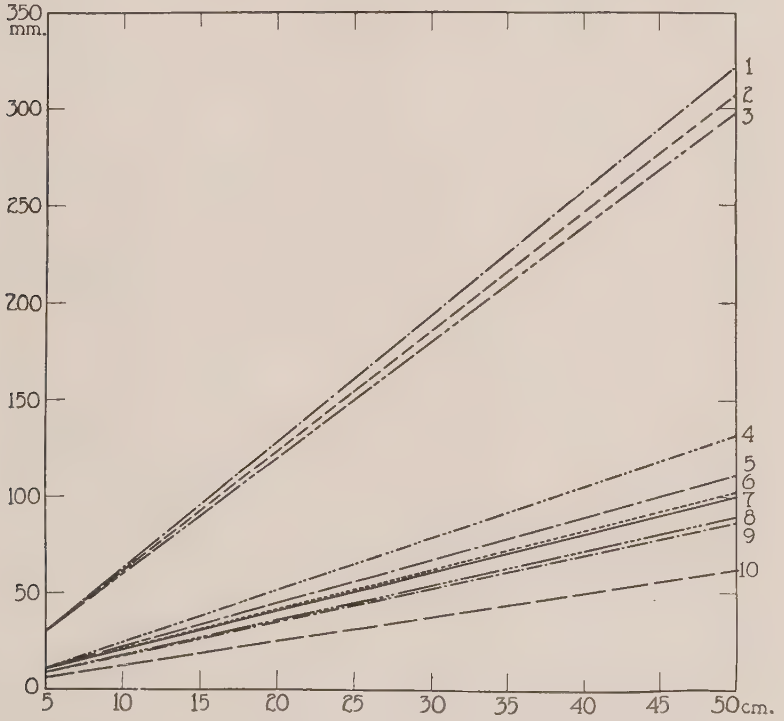
Calculated Values of the External Dimensions of the Thorax and Abdomen at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Formulae		Calculated values (mm.) at crown-heel lengths of:									
	a	b	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Bi-acromial diameter	.225	±0.0	11.3	22.5	33.8	45.0	56.3	67.5	78.8	90.0	101.3	112.5
Nipple to nipple distance	.125	±0.0	6.3	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5
Bi-deltoid circumference	.6525	-2.5	30.1	62.8	95.4	128.0	160.6	193.3	225.9	258.5	291.1	323.8
" " diameter	.27	-2.5	11.0	24.5	38.0	51.5	65.0	78.5	92.0	105.5	119.0	132.5
Circumference of thorax at nipples	.6	±0.0	30.0	60.0	90.0	120.0	150.0	180.0	210.0	240.0	270.0	300.0
Transverse diameter at nipples	.2025	±0.0	10.1	20.3	30.4	40.5	50.6	60.8	70.9	81.0	91.1	101.3
Antero-posterior diameter at nipples	.175	±0.0	8.8	17.5	26.3	35.0	43.8	52.5	61.3	70.0	78.8	87.5
Circumference at xiphi-sternal junction	.62	-1.0	30.0	61.0	92.0	123.0	154.0	185.0	216.0	247.0	278.0	309.0
Transverse diameter at xiphi-sternal junction	.205	±0.0	10.3	20.5	30.8	41.0	51.3	61.5	71.8	82.0	92.3	102.5
Antero-posterior " " " " "	.18	±0.0	9.0	18.0	27.0	36.0	45.0	54.0	63.0	72.0	81.0	90.0
Circumference at tenth rib	.64	-4.0	28.0	60.0	92.0	124.0	156.0	188.0	220.0	252.0	284.0	316.0
Transverse diameter at tenth rib	.2075	-1.0	9.4	19.8	30.1	40.5	50.9	61.3	71.6	82.0	92.4	102.8
Antero-posterior diameter at tenth rib	.1825	-1.0	8.1	17.3	26.4	35.5	44.6	53.8	62.9	72.0	81.1	90.3
Circumference at umbilicus	.5525	-5.5	22.1	49.8	77.4	105.0	132.6	160.3	187.9	215.5	243.1	270.8
Transverse diameter at umbilicus	.19	-2.0	7.5	17.0	26.5	36.0	45.5	55.0	64.5	74.0	83.5	93.0
Antero-posterior diameter at umbilicus	.165	-1.0	7.3	15.5	23.8	32.0	40.3	48.5	56.8	65.0	73.3	81.5
Sternal notch to pubis	.28 .4	+1.5 $-2\sqrt{X+2}$	15.5	29.5	43.5	57.5	71.5	85.5	104.6	122.0	139.6	157.3
" " " umbilicus	.22 .27	+1.5 -11.0	12.5	23.5	34.5	45.5	56.5	70.0	83.5	97.0	110.5	124.0
" " " xiphi-sternal junction	.11	-1.5	4.0	9.5	15.0	20.5	26.0	31.5	37.0	42.5	48.0	53.5
Xiphi-sternal junction to pubis	.19 .26	+1.5 -16.0	11.0	20.5	30.0	39.5	49.0	62.0	75.0	88.0	101.0	114.0
" " " " umbilicus	.125 .18	+1.75 -12.0	8.0	14.3	20.5	26.8	33.0	42.0	51.0	60.0	69.0	78.0
Umbilicus to pubis	.072 .09	-0.5 -5.0	3.1	6.7	10.3	13.9	17.5	22.0	26.5	31.0	35.5	40.0

crown-heel length of the body, 17 are expressions for simple straight lines, 4 represent phased straight lines, and 1 is a straight line for the first portion of the progression and a concave curve for the latter portion. The phased formulae all represent dimensions which lie in the median line of the ventral surface of the trunk and which, as we have already pointed out, are probably influenced by the posture of the body. Of the 17 simple formulae, as determined by graphic methods, 7 have zero *b* constants while the remainder have negative or minus *b* constants. Those dimensions having formulae with zero *b*

FIGURE 42

The Growth of the External Dimensions of the Thorax (as Determined by Empirical Formulae) in the Fetal Period with Respect to Growth in Crown-Heel Length



Abscissa: Crown-heel length (cm). Ordinates: External dimensions of the thorax (mm).

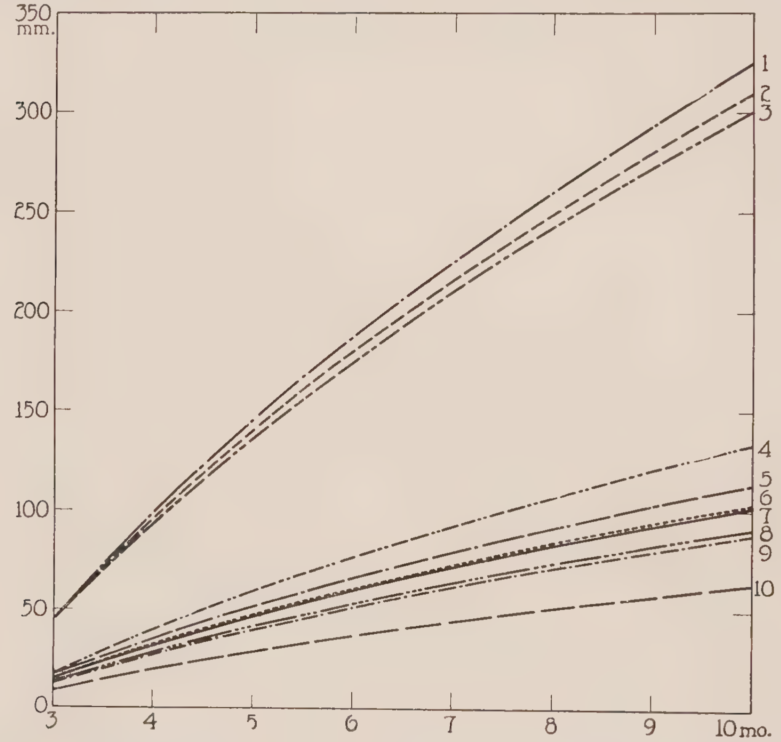
1. Bi-deltoid circumference
2. Circumference at the xiphi-sternal junction
3. Circumference at the nipples
4. Bi-deltoid diameter
5. Bi-acromial diameter
6. Transverse diameter at the xiphi-sternal junction
7. Transverse diameter at the nipples
8. Antero-posterior diameter at the xiphi-sternal junction
9. Antero-posterior diameter at the nipples
10. Nipple to nipple (bi-mammary) distance

constants are all associated with the upper or thoracic portion of the trunk, while those with negative constants represent the dimensions of the lower or abdominal portion.

Table 98 and figures 42 and 45 present the calculated values for these dimensions in relation to the standing-height or total body-length. The calculated absolute and percentage increments of each of these dimensions for each 5 cm interval of total body-length, from 5 to 50 cm, inclusive, are given in connection with the special tables for the individual measurements.

FIGURE 43

The Growth of the External Dimensions of the Body (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: External dimensions of the thorax (mm).

1. Bi-deltoid circumference
2. Circumference at the xiphi-sternal junction
3. Circumference at the nipples
4. Bi-deltoid diameter
5. Bi-acromial diameter
6. Transverse diameter at the xiphi-sternal junction
7. Transverse diameter at nipples
8. Antero-posterior diameter at xiphi-sternal junction
9. Antero-posterior diameter at nipples
10. Nipple to nipple (bi-mammary) distance

Table 99 and figures 43 and 46 present the calculated values for the dimensions of the trunk at the close of each month of the fetal period from three months to birth, inclusive.

The absolute and percentage increments of these dimensions in each month of the fetal period are shown in tables 100 and 101. In the fourth month the absolute increments range from 6.1 mm to 55.2 mm. In the sixth month they range between 5.4 mm and 41.8 mm, and in the tenth month from 4.3 to 30.9. The distance from the umbilicus to the pubis shows throughout the period the minimum absolute monthly gain for the group, and the bi-deltoid circumference makes the maximum absolute gain. All of the external dimensions of the trunk show a steady decline in absolute monthly increments in the fetal period, with the exception of the distance from the xiphi-sternal junction to the pubis, the distance from the xiphi-sternal

TABLE 99

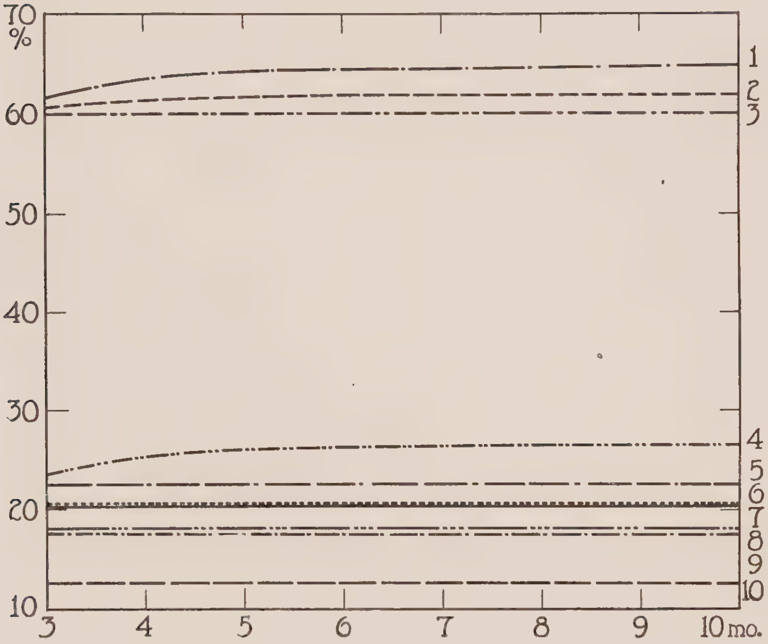
Calculated Values of the External Dimensions of the Thorax and Abdomen at the Close of Each Month of the Fetal Period

Dimension	Formulae		Calculated values (mm.) at:							
	a	b	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Bi-acromial diameter	.225	±0.0	15.9	35.0	51.3	65.7	78.9	91.0	102.3	113.0
Nipple to nipple distance	.125	±0.0	8.9	19.4	28.5	36.5	43.8	50.5	56.8	62.8
Bi-deltoid circumference	.6525	-2.5	43.7	98.9	146.2	188.0	226.2	261.3	294.2	325.1
" " diameter	.27	-2.5	16.6	39.5	59.0	76.3	92.1	106.7	120.3	133.0
Circumference of thorax, at nipples	.6	±0.0	42.5	93.2	136.7	175.2	210.3	242.6	272.8	301.2
Transverse diameter at nipples	.2025	±0.0	14.3	31.5	46.1	59.1	71.0	81.9	92.1	101.7
Antero-posterior diameter at nipples	.175	±0.0	12.4	27.2	39.9	51.1	61.3	70.8	79.6	87.9
Circumference at xiphi-sternal junction	.62	-1.0	42.9	95.3	140.2	180.0	216.3	249.7	280.9	310.2
Transverse diameter at xiphi-sternal junction	.205	±0.0	14.5	31.9	46.7	59.9	71.9	82.9	93.2	102.9
Antero-posterior " " " "	.18	±0.0	12.7	28.0	41.0	52.6	63.1	72.8	81.8	90.4
Circumference at tenth rib	.64	-4.0	41.3	95.5	141.9	182.9	220.3	254.8	287.0	317.3
Transverse diameter at tenth rib	.2075	-1.0	13.7	31.2	46.3	59.6	71.7	82.9	93.4	103.2
Antero-posterior diameter at tenth rib	.1825	-1.0	11.9	27.4	40.6	52.3	63.0	72.8	82.0	90.6
Circumference at umbilicus	.5525	-5.5	33.6	80.4	120.4	155.8	188.2	217.9	245.7	271.9
Transverse diameter at umbilicus	.19	-2.0	11.5	27.5	41.3	53.5	64.6	74.8	84.4	93.4
Antero-posterior diameter at umbilicus	.165	-1.0	10.7	24.6	36.6	47.2	56.8	65.7	74.0	81.8
Sternal notch to pubis	.28 .4	+1.5 $-\sqrt{x+2}$	21.3	45.0	65.3	83.3	104.8	123.5	141.3	158.0
" " " umbilicus	.22 .27	+1.5 -11.0	17.1	35.7	51.6	67.8	83.6	98.2	111.8	124.5
" " " xiphi-sternal junction	.11	-1.5	6.3	15.6	23.6	30.6	37.1	43.0	48.5	53.7
Xiphi-sternal junction to pubis	.19 .26	+1.5 -16.0	15.0	31.0	44.8	59.9	75.1	89.1	102.2	114.5
" " " " umbilicus	.125 .18	+1.75 -12.0	10.6	21.2	30.2	40.6	51.1	60.8	69.8	78.4
Umbilicus to pubis	.072 .09	-0.5 -5.0	4.6	10.7	15.9	21.3	26.5	31.4	35.9	40.2

junction to the umbilicus, and the distance from the umbilicus to the pubis, which show increased absolute gains in the sixth and seventh months. The absolute gains in these dimensions may be associated with the rapid growth of certain of the abdominal viscera that occurs at about this time.

FIGURE 44

The Changes in the Relative Size of the External Dimensions of the Thorax in the Fetal Period



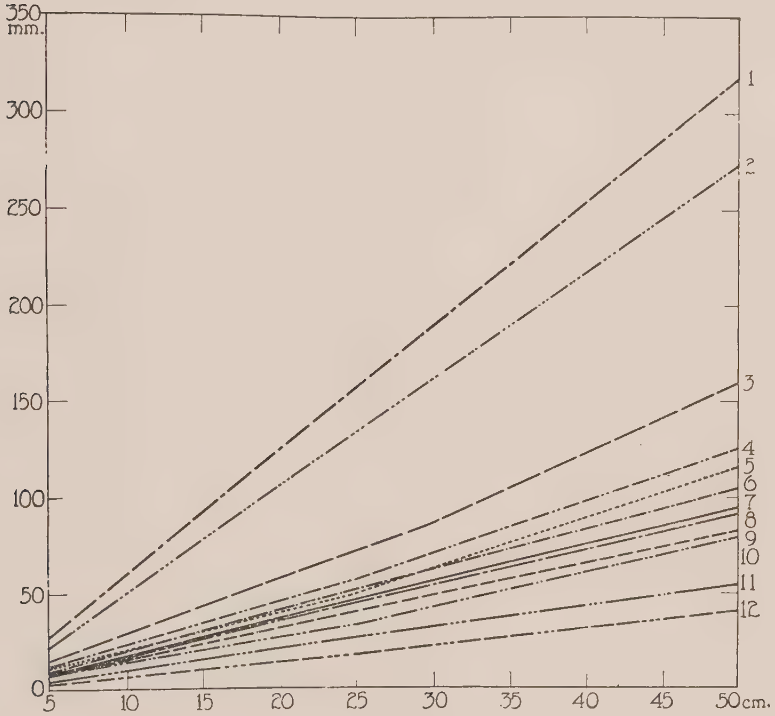
Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the external dimensions of the thorax expressed as per cents of the crown-heel length.

1. Bi-deltoid circumference
2. Circumference at the xiphi-sternal junction
3. Circumference at nipples
4. Bi-deltoid diameter
5. Bi-acromial diameter
6. Transverse diameter at xiphi-sternal junction
7. Transverse diameter at nipples
8. Antero-posterior diameter at xiphi-sternal junction
9. Antero-posterior diameter at nipples
10. Nipple to nipple (bi-mammary) distance

The percentage increments in the fourth month range from 100 for the distance from the xiphi-sternal junction to the umbilicus, to 147.6 for the distance from the sternal notch to the xiphi-sternal junction. The majority of the measurements show percentage increments between 119 and 133 in this period. In the seventh month the increments range from 20.0 per cent for the majority of the thoracic measurements to 25.9 per cent for the distance from the xiphi-sternal junction to the umbilicus. In the ninth month the range of increments is reduced to 12.5 to 15.3 per cent, while in the last month of the fetal period most of the dimensions of the trunk show increases of between 10 and 11 per cent, although the percentage gains in the median line measurements are slightly higher.

FIGURE 45

THE GROWTH OF THE EXTERNAL DIMENSIONS OF THE ABDOMEN (AS DETERMINED BY EMPIRICAL FORMULAE) IN THE FETAL PERIOD WITH RESPECT TO GROWTH IN CROWN-HEEL LENGTH



Abscissa: Crown-heel length (cm). Ordinates: External dimensions of the abdomen (mm).

1. Circumference at the tenth rib
2. Circumference at the umbilicus.
3. Distance from sternal notch to pubis
4. Distance from sternal notch to umbilicus
5. Distance from xiphi-sternal junction to pubis
6. Transverse diameter at the tenth rib
7. Transverse diameter at the umbilicus
8. Antero-posterior diameter at the tenth rib
9. Antero-posterior diameter at the umbilicus
10. Distance from xiphi-sternal junction to umbilicus
11. Distance from sternal notch to xiphi-sternal junction
12. Distance from umbilicus to pubis

Table 102 shows the percentage of the natal value attained by each external dimension of the trunk at each 5 cm interval of total body-length from 5 to 50 cm, inclusive. At 5 cm most of the chest dimensions have attained approximately 10 per cent of their natal values, while all of the median-line dimensions and all of the dimensions of the abdomen have acquired from 7.5 to 10 per cent of their computed natal values. At 25 cm crown-heel length the range of attained values extends from 42.3 per cent for the distance from the xiphi-sternal junction to the umbilicus, to 50 per cent for most of the dimensions of the thorax. Seventeen of the 22 dimensions have acquired between 48 and 50 per cent of their natal sizes at this stage. At 45 cm crown-heel length most of the trunk dimensions have acquired about nine-tenths of their natal size, the range being from 88.5 per cent for the

TABLE 100

Calculated Absolute Increments of the External Dimensions of the Thorax and Abdomen in Each Month of the Fetal Period

Dimension	Absolute increments (mm.) in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Bi-acromial diameter	19.0	16.3	14.4	13.2	12.1	11.3	10.6
Nipple to nipple distance	10.6	9.1	8.0	7.3	6.7	6.3	5.9
Bi-deltoid circumference	55.2	47.3	41.8	38.2	35.1	32.9	30.9
" " diameter	22.8	19.6	17.3	15.8	14.5	13.6	12.8
Circumference of thorax at nipples	50.8	43.5	38.7	35.1	32.3	30.2	28.4
Transverse diameter at nipples	17.1	14.7	13.1	11.8	10.9	10.2	9.6
Antero-posterior diameter at nipples	14.8	12.7	11.2	10.2	9.4	8.8	8.3
Circumference at xiphi-sternal junction	52.4	45.0	39.8	36.3	33.4	31.2	29.3
Transverse diameter at xiphi-sternal junction	17.3	14.9	13.2	12.0	11.0	10.3	9.7
Antero-posterior " " " " "	15.2	13.1	11.5	10.5	9.7	9.1	8.5
Circumference at tenth rib	54.1	46.4	41.0	37.4	34.4	32.3	30.3
Transverse diameter at tenth rib	17.5	15.0	13.3	12.1	11.2	10.5	9.8
Antero-posterior diameter at tenth rib	15.4	13.2	11.7	10.7	9.8	9.2	8.6
Circumference at umbilicus	46.7	40.1	35.4	32.3	29.7	27.8	26.1
Transverse diameter at umbilicus	16.1	13.8	12.2	11.1	10.2	9.6	9.0
Antero-posterior diameter at umbilicus	14.0	12.0	10.6	9.7	8.9	8.3	7.8
Sternal notch to pubis	23.7	20.3	17.9	21.5	18.7	17.8	16.7
" " " umbilicus	18.6	16.0	16.2	15.8	14.5	13.6	12.8
" " " xiphi-sternal junction	9.3	8.0	7.1	6.4	5.9	5.5	5.2
Xiphi-sternal junction to pubis	16.1	13.8	15.1	15.2	14.0	13.1	12.3
" " " " umbilicus	10.6	9.1	10.4	10.5	9.7	9.1	8.5
Umbilicus to pubis	6.1	5.2	5.4	5.3	4.8	4.5	4.3

distance from the xiphi-sternal junction to the umbilicus, to 88.5 and 90.0 for most of the thoracic dimensions.

At three fetal months most of the dimensions of the trunk have attained between 11.4 and 14.1 per cent of their birth size. At six months all of the dimensions are somewhat more than half their natal size, the range being from 51.8 per cent for the distance from the xiphi-sternal junction to the umbilicus, to 58.2 per cent for a number of the upper thoracic dimensions. At nine months the attained values range from 89.0 to 90.6 per cent, and 18 of the 22 dimensions have completed between 90 and 90.6 per cent of their prenatal growth.

TABLE 101

Calculated Percentage Increments of the External Dimensions of the Thorax and Abdomen in Each Month of the Fetal Period

Dimension	Percentage increments in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Bi-acromial diameter	119.5	46.7	28.1	20.0	15.3	12.5	10.4
Nipple to nipple distance	119.1	46.7	28.1	20.0	15.3	12.5	10.4
Bi-deltoid circumference	126.3	47.8	28.6	20.3	15.5	12.6	10.5
" " diameter	137.3	49.6	29.3	20.6	15.7	12.7	10.6
Circumference of thorax at nipples	119.5	46.7	28.1	20.0	15.3	12.5	10.4
Transverse diameter at nipples	119.6	46.7	28.1	20.0	15.3	12.5	10.4
Antero-posterior diameter at nipples	119.4	46.7	28.1	20.0	15.3	12.5	10.4
Circumference at xiphi-sternal junction	122.1	47.2	28.4	20.2	15.4	12.5	10.4
Transverse diameter at xiphi-sternal junction	119.3	46.7	28.1	20.0	15.3	12.5	10.4
Antero-posterior " " " "	119.7	46.7	28.1	20.0	15.3	12.5	10.4
Circumference at tenth rib	131.0	48.6	28.9	20.4	15.6	12.7	10.6
Transverse diameter at tenth rib	127.7	48.1	28.7	20.3	15.6	12.6	10.5
Antero-posterior diameter at tenth rib	129.4	48.2	28.8	20.5	15.6	12.6	10.5
Circumference at umbilicus	139.0	49.9	29.4	20.7	15.8	12.8	10.6
Transverse diameter at umbilicus	140.0	50.2	29.5	20.7	15.8	12.8	10.7
Antero-posterior diameter at umbilicus	130.8	48.8	29.0	20.6	15.7	12.6	10.5
Sternal notch to pubis	111.3	45.1	27.4	25.8	17.8	14.4	11.8
" " " umbilicus	108.8	44.8	31.4	23.3	17.3	13.8	11.4
" " " xiphi-sternal junction	147.6	51.3	30.1	20.9	15.9	12.8	10.7
Xiphi-sternal junction to pubis	107.3	44.5	33.7	25.4	18.6	14.7	12.0
" " " " umbilicus	100.0	42.9	34.4	25.9	19.0	15.0	12.2
Umbilicus to pubis	132.6	48.6	34.0	24.9	18.1	15.3	12.0

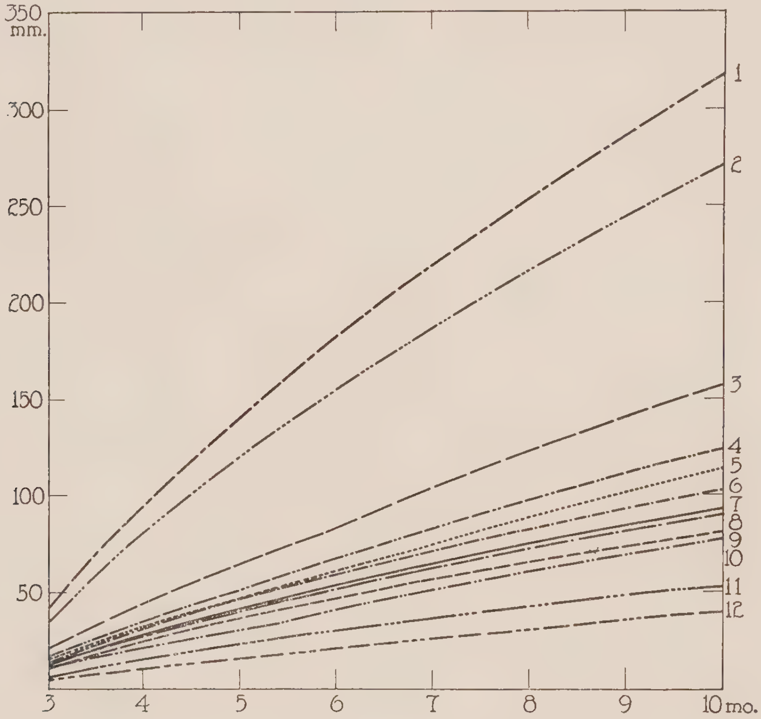
The relative values of the various trunk dimensions at each 5 cm interval of crown-heel length from 5 to 50 cm, inclusive, are shown in table 104. At 5 cm crown-heel length these range from 6.2 per cent to 60.2 per cent; at 25 cm crown-heel length the range extends from

7.0 per cent to 64.2 per cent; and at 50 cm, from 8.0 per cent to 64.8 per cent. At each of these intervals the distance from the umbilicus to the pubis has the least, and the bi-deltoid circumference has the greatest, relative size of this group of dimensions.

The relative sizes of the various trunk dimensions at each month of the fetal period are shown in table 105 and figures 44 and 47. At three months these values range from 61.7 per cent for the bi-deltoid circumference, to 6.5 per cent for the distance from the pubis

FIGURE 46

The Growth of the External Dimensions of the Abdomen (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: External dimensions of the abdomen (mm).

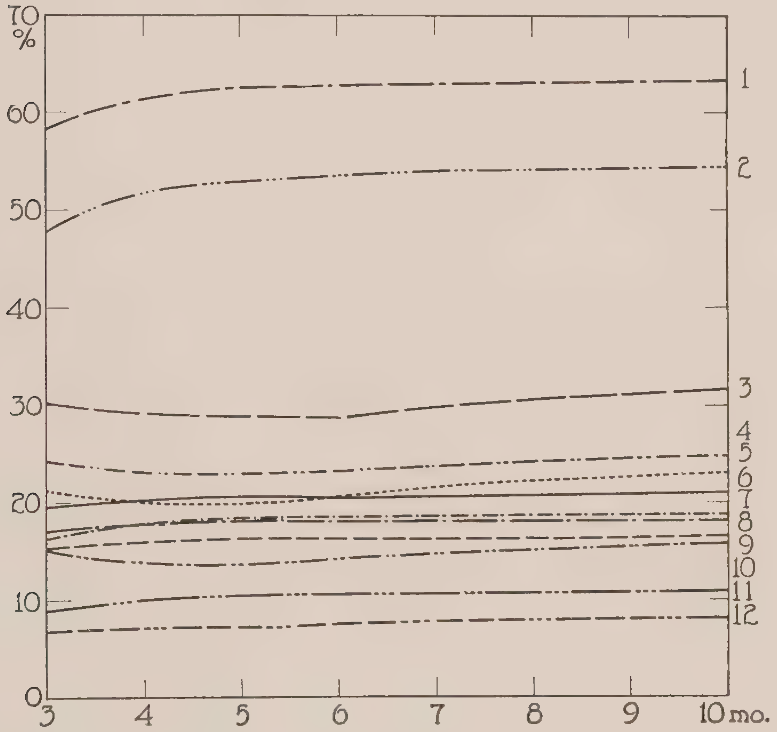
1. Circumference at the tenth rib
2. Circumference at the umbilicus
3. Distance from sternal notch to pubis
4. Distance from sternal notch to umbilicus
5. Distance from xiphi-sternal junction to pubis
6. Transverse diameter at tenth rib
7. Transverse diameter at umbilicus
8. Antero-posterior diameter at tenth rib
9. Antero-posterior diameter at umbilicus
10. Distance from xiphi-sternal junction to umbilicus
11. Distance from sternal notch to xiphi-sternal junction
12. Distance from umbilicus to pubis

to the umbilicus. At six months the range is from 64.4 per cent to 7.3 per cent, and at ten months it is from 64.8 to 8.0 per cent, for the same dimensions.

As indicated by our empirical formulae, there is a marked difference in trend in the various relative dimensions of the trunk in the fetal period. Using the values obtained from the empirical formulae developed by graphic methods, it is found that 7 dimensions, all of the

FIGURE 47

The Changes in the Relative Size of the External Dimensions of the Abdomen in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the external dimensions of the abdomen expressed as per cents of the crown-heel length.

1. Circumference at tenth rib
2. Circumference at umbilicus
3. Distance from sternal notch to pubis
4. Distance from sternal notch to umbilicus
5. Distance from xiphi-sternal junction to pubis
6. Transverse diameter at tenth rib
7. Transverse diameter at umbilicus
8. Antero-posterior diameter at tenth rib
9. Antero-posterior diameter at umbilicus
10. Distance from xiphi-sternal junction to umbilicus
11. Distance from sternal notch to xiphi-sternal junction
12. Distance from umbilicus to pubis

thorax, show no change in relative size with respect to crown-heel length during the fetal period, while the remaining 15 show increases in relative as well as absolute size. Thirteen of the latter group show an increase of less than 5 per cent. The two largest changes are in the circumference at the level of the tenth rib and in the circumference at the umbilicus, which make gains in relative size of 7.2 and of 10.0 per cent, respectively, between 5 and 50 cm crown-heel length.

TABLE 102

Per Cent of Natal Value Attained by Each External Dimension of the Thorax and Abdomen at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Percentage of natal value at crown-heel lengths of:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Bi-acromial diameter	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Nipple to nipple distance	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Bi-deltoid circumference	9.3	19.4	29.5	39.5	49.6	59.7	69.8	79.8	90.0	100.0
" " diameter	8.3	18.5	28.7	38.9	49.1	59.2	69.4	79.6	89.8	100.0
Circumference of thorax at nipples	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Transverse diameter at nipples	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Antero-posterior diameter at nipples	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Circumference at xiphi-sternal junction	9.7	19.7	29.8	39.8	49.8	59.9	69.9	79.9	90.0	100.0
Transverse diameter at xiphi-sternal junction	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Antero-posterior " " " " "	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0
Circumference at tenth rib	8.9	19.0	29.1	39.2	49.4	59.5	69.6	79.7	89.9	100.0
Transverse diameter at tenth rib	9.1	19.3	29.3	39.4	49.5	59.6	69.7	79.8	89.9	100.0
Antero-posterior diameter at tenth rib	9.0	19.2	29.2	39.3	49.4	59.6	69.7	79.7	89.8	100.0
Circumference at umbilicus	8.2	18.4	28.6	38.8	49.0	59.2	69.4	79.6	89.8	100.0
Transverse diameter at umbilicus	8.1	18.3	28.5	38.7	48.9	59.1	69.4	79.6	89.8	100.0
Antero-posterior diameter at umbilicus	9.0	19.0	29.2	39.3	49.4	59.5	69.7	79.8	89.9	100.0
Sternal notch to pubis	9.9	18.8	27.7	36.6	45.5	54.4	66.5	77.6	88.7	100.0
" " " umbilicus	10.0	19.0	27.8	36.7	45.6	56.5	67.3	78.2	89.1	100.0
" " " xiphi-sternal junction	7.5	17.8	28.0	38.3	48.6	58.9	69.2	79.4	89.7	100.0
Xiphi-sternal junction to pubis	9.6	18.0	26.3	34.7	43.0	54.4	65.8	77.2	88.6	100.0
" " " " umbilicus	10.3	18.3	26.3	34.4	42.3	53.9	65.4	76.9	88.5	100.0
Umbilicus to pubis	7.8	16.8	25.8	34.8	43.8	55.0	66.3	77.5	88.8	100.0

Some of the changes in the proportions of the trunk may be illustrated by the use of indices. The relation of the breadth of the trunk to its height may be expressed by a value obtained by dividing the computed bi-acromial diameter by the computed distance from the sternal notch to the pubis and multiplying the result by 100. This figure is 72.9 at 5 cm crown-heel length, 78.7 at 25 cm, and 71.5 at

50 cm; and 74.4 at three fetal months, 78.9 at six months, and 71.5 at ten months or birth. The relation of the girth of the trunk to its length may be expressed by an index formed by dividing the computed circumference at the level of the nipples by the computed distance from the sternal notch to the pubis and multiplying the result by 100. This index is 193.5 at 5 cm crown-heel length, 209.8 at 25 cm, and 190.7 at 50 cm; and 199.5 at three fetal months, 210.3 at six months, and 190.6 at ten months or birth. Thus apparently the trunk is more slender in the early part of the fetal period than in the middle portion, but is again reduced in breadth before birth. But we must point out that these indices are based upon the use of the distance from the sternal notch to the pubis, which we have computed as a bi-phased curve, and which we regard as probably distinctly affected

TABLE 103

Per Cent of Natal Value Attained by Each External Dimension of the Thorax and Abdomen at the Close of Each Month of the Fetal Period

Dimension	Percentage of natal value at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Bi-acromial diameter	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0
Nipple to nipple distance	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0
Bi-deltoid circumference	13.4	30.4	45.0	57.8	69.6	80.4	90.5	100.0
" " diameter	12.5	29.7	44.4	57.4	69.2	80.2	90.5	100.0
Circumference of thorax at nipples	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0
Transverse diameter at nipples	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0
Antero-posterior diameter at nipples	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0
Circumference at xiphi-sternal junction	13.8	30.7	45.2	58.0	69.7	80.5	90.6	100.0
Transverse diameter at xiphi-sternal junction	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0
Antero-posterior " " " " "	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0
Circumference at tenth rib	13.0	30.1	44.7	57.6	69.4	80.3	90.5	100.0
Transverse diameter at tenth rib	13.3	30.2	44.9	57.8	69.5	80.3	90.5	100.0
Antero-posterior diameter at tenth rib	13.1	30.2	44.8	57.7	69.5	80.4	90.5	100.0
Circumference at umbilicus	12.4	29.6	44.2	57.3	69.2	80.1	90.4	100.0
Transverse diameter at umbilicus	12.3	29.4	44.2	57.3	69.2	80.1	90.4	100.0
Antero-posterior diameter at umbilicus	13.1	30.1	44.7	57.7	69.4	80.3	90.4	100.0
Sternal notch to pubis	13.5	28.5	41.3	52.7	66.3	78.2	90.0	100.0
" " " umbilicus	13.7	28.7	41.4	54.5	67.1	78.9	89.8	100.0
" " " xiphi-sternal junction	11.7	29.1	43.9	57.0	69.1	80.1	90.3	100.0
Xiphi-sternal junction to pubis	13.1	27.1	39.1	52.3	65.6	77.8	89.3	100.0
" " " " umbilicus	13.5	27.0	38.5	51.8	65.2	77.6	89.0	100.0
Umbilicus to pubis	11.4	26.6	39.6	53.0	65.9	78.1	89.3	100.0

by posture. The data of Friedenthal, Lafaille, and Reicher (figure 40, tables 175 and 180) on this dimension do not show this bi-phased progression, and we think it most probable that were the artifacts of posture properly eliminated from our data the relation of this dimension to crown-heel length would be best expressed as a straight line. Were this the case, the indices would show a constant reduction during the fetal period. The second of these indices has been determined by Schultz, who found it to be 238 per cent in fetuses of nine weeks and to decrease to 178 per cent in the newborn.

TABLE 104

Relative Size of the External Dimensions of the Thorax and Abdomen (Computed as Per Cents of the Crown-Heel Length) at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Per cent. of total (crown-heel) length at:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Bi-acromial diameter	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Nipple to nipple distance	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Bi-deltoid circumference	60.2	62.8	63.6	64.0	64.2	64.4	64.5	64.6	64.7	64.8
" " diameter	22.0	24.5	25.3	25.8	26.0	26.2	26.3	26.4	26.4	26.5
Circumference of thorax at nipples	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Transverse diameter at nipples	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
Antero-posterior diameter at nipples	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Circumference at xiphi-sternal junction	60.0	61.0	61.3	61.5	61.6	61.7	61.7	61.8	61.8	61.8
Transverse diameter at xiphi-sternal junction	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Antero-posterior " " " " "	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Circumference at tenth rib	56.0	60.0	61.3	62.0	62.4	62.7	62.9	63.0	63.1	63.2
Transverse diameter at tenth rib	18.8	19.8	20.1	20.3	20.4	20.4	20.5	20.5	20.5	20.6
Antero-posterior diameter at tenth rib	16.2	17.3	17.6	17.8	17.8	17.9	18.0	18.0	18.0	18.1
Circumference at umbilicus	44.2	49.8	51.6	52.5	53.0	53.4	53.7	53.9	54.0	54.2
Transverse diameter at umbilicus	15.0	17.0	17.7	18.0	18.2	18.3	18.4	18.5	18.6	18.6
Antero-posterior diameter at umbilicus	14.6	15.5	15.9	16.0	16.1	16.2	16.2	16.3	16.3	16.3
Sternal notch to pubis	31.0	29.5	29.0	28.8	28.6	28.5	29.9	30.5	31.0	31.5
" " " umbilicus	25.0	23.5	23.0	22.8	22.6	23.3	23.9	24.3	24.6	24.8
" " " xiphi-sternal junction	8.0	9.5	10.0	10.3	10.4	10.5	10.6	10.6	10.7	10.7
Xiphi-sternal junction to pubis	22.0	20.5	20.0	19.8	19.6	20.7	21.4	22.0	22.4	22.8
" " " " umbilicus	16.0	14.3	13.7	13.4	13.2	14.0	14.6	15.0	15.3	15.6
Umbilicus to pubis	6.2	6.7	6.8	7.0	7.0	7.3	7.6	7.8	7.9	8.0

A number of indices may be employed for expressing the form changes in the chest. Of these, the one most generally used is the thoracic index, computed by dividing the antero-posterior diameter of the thorax by the transverse diameter and multiplying the result by 100. The thoracic index at the level of the nipples is 87.1 at 5 cm crown-heel length, 86.6 at 25 cm, and 86.4 at 50 cm; and 86.7 at three fetal months, 86.5 at six months, and 86.4 at birth. At the level of the xiphi-sternal junction, this index is 87.4 at 5 cm crown-heel length, 87.7 at 25 cm, and 87.8 at 50 cm; and 87.6 at three fetal months, 87.8 at six months, and 87.9 at birth. The index at the level of the tenth rib is 86.2 at 5 cm crown-heel length, 87.6 at 25 cm, and 87.8 at 50 cm; and 86.9 at three fetal months, 87.8 at six months, and 87.8 at ten months or birth. These figures indicate that there is little change in the relation between the breadth and depth of the chest in the fetal period, although the upper portion of the thorax seems to flatten slightly in this interval, while the middle portion remains practically constant, and the lower portion undergoes a very slight

TABLE 105

RELATIVE SIZE OF THE EXTERNAL DIMENSIONS OF THE THORAX AND ABDOMEN (COMPUTED AS PER CENTS OF THE CROWN-HEEL LENGTH) AT THE CLOSE OF EACH MONTH OF THE FETAL PERIOD

Dimension	Per cent. of total (crown-heel) length at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Bi-acromial diameter	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5
Nipple to nipple distance	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Bi-deltoid circumference	61.7	63.6	64.2	64.4	64.5	64.6	64.7	64.8
" " diameter	23.4	25.4	25.9	26.1	26.3	26.4	26.5	26.5
Circumference of thorax at nipples	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Transverse diameter at nipples	20.3	20.3	20.3	20.3	20.3	20.3	20.3	20.3
Antero-posterior diameter at nipples	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Circumference at xiphi-sternal junction	60.6	61.3	61.5	61.6	61.7	61.8	61.8	61.8
Transverse diameter at xiphi-sternal junction	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Antero-posterior " " " " "	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Circumference at tenth rib	58.3	61.5	62.3	62.6	62.9	63.0	63.1	63.2
Transverse diameter at tenth rib	19.4	20.1	20.3	20.4	20.5	20.5	20.5	20.6
Antero-posterior diameter at tenth rib	16.8	17.6	17.8	17.9	18.0	18.0	18.0	18.0
Circumference at umbilicus	47.5	51.7	52.8	53.4	53.7	53.9	54.0	54.2
Transverse diameter at umbilicus	16.2	17.7	18.1	18.3	18.4	18.5	18.6	18.6
Antero-posterior diameter at umbilicus	15.1	15.8	16.1	16.2	16.2	16.3	16.3	16.3
Sternal notch to pubis	30.1	29.0	28.7	28.5	29.9	30.5	31.1	31.5
" " " umbilicus	24.2	23.0	22.6	23.2	23.9	24.3	24.6	24.8
" " " xiphi-sternal junction	8.9	10.0	10.4	10.5	10.6	10.6	10.7	10.7
Xiphi-sternal junction to pubis	21.2	19.9	19.7	20.5	21.4	22.0	22.5	22.8
" " " " umbilicus	15.0	13.6	13.3	13.9	14.6	15.0	15.4	15.6
Umbilicus to pubis	6.5	6.9	7.0	7.3	70.6	7.8	7.9	8.0

increase in relative depth. Schultz, who measured the thoracic diameters at the level of the junction of the fourth pair of ribs with the sternum, found an increase in the transverse, as compared with the sagittal diameter.

The relative growth in girth of the upper and lower parts of the thorax may be expressed as an index by dividing the computed circumference at the nipples by the computed circumference at the tenth rib and multiplying the result by 100. The values obtained are: 108.0 at 5 cm crown-heel length, 98.3 at 25 cm, and 96.7 at 50 cm; and 104.2 at three fetal months, 97.8 at six months, and 97.2 at ten months or birth. These figures indicate that the lower portion of the thorax grows relatively more rapidly than the upper portion. In other words, the angle of the thoracic cone is becoming more acute during the fetal period. This change may be due to the flaring of the lateral thoracic walls inferiorly through the increase in mass of the abdominal viscera, and particularly to the growth of the intestinal mass, which as has been pointed out by Cameron, is very marked in the latter part of fetal life.

Some concept of the growth in length of the thorax as compared with its depth and breadth may be obtained by dividing the computed distance from the sternal notch to the xiphi-sternal junction by the computed diameter of the thorax and multiplying the result by 100. This index, calculated for the transverse diameter at the level of the nipples, is 39.6 at 5 cm crown-heel length, 51.4 at 25 cm, and 52.8 at 50 cm; and 44.1 at three fetal months, 51.8 at six months, and 52.8 at ten months or birth. A similar index made with the use of the computed transverse diameter at the xiphi-sternal junction gives approximately the same figures. The values obtained by dividing the distance from the sternal notch to the xiphi-sternal junction by the antero-posterior diameter at the nipples are: 45.5 at 5 cm crown-heel length, 59.4 at 25 cm, and 61.1 at 50 cm; and 50.8 at three fetal months, 59.9 at six months, and 61.1 at ten months or birth. Similar values are obtained when the antero-posterior diameter at the xiphi-sternal junction is used in computing this index. These figures indicate that the thorax is becoming more elongated both in relation to its transverse and to its antero-posterior diameters during the fetal period, and support the general concept that the trunk becomes more slender in this interval.

The growth of the girths of the upper and lower parts of the trunk may be expressed by an index computed by dividing the calculated circumference at the nipples by the calculated circumference at the umbilicus and multiplying the result by 100. This index is 135.7 at 5 cm crown-heel length, 113.1 at 25 cm, and 110.8 at 50 cm; and 126.5 at three fetal months, 112.5 at six months, and 110.8 at ten months or birth. Thus the girth of the abdomen is growing more rapidly than that of the upper portion of the thorax. This conclusion is in harmony with the findings given above for the relation between the circumferences of the upper and lower parts of the chest.

PART VI

SUMMARY OF FINDINGS ON THE EXTERNAL DIMENSIONS OF THE PELVIS

I. Introductory Note

The fetal growth of the pelvic region was studied by measurements of six pelvic dimensions. Four of these, the intercristal, the interspinous, the external conjugate, and the intertrochanteric diameters, are standard pelvic dimensions. The remaining two, the height of the pelvis and the bi-tuberous distance, are less commonly measured. All of these dimensions are linear determinations, four being transverse diameters, one a cranio-caudal distance, and one an antero-posterior (dorso-ventral) diameter. One of these dimensions (the intertrochanteric diameter) involves parts of the inferior extremities as well as the pelvis proper.

II. Consideration of Individual Dimensions*

49. Height of Pelvis (Crest of Ilium to Rump)

(Field Graph 49, Table 106)

This dimension represents the greatest vertical distance from the highest point of the crest of the ilium to the soft tissues over the tuberosity of the ischium. This is one of the few dimensions that shows a slight reduction with injection and subsequent preservation in formalin. Injection alone produces a diminution of 0.2 per cent in this dimension, and this decrease continues rather steadily to 4.6 per cent after six months' preservation.

Table 106 gives a summary of our findings regarding the height of the pelvis in the fetal period. The calculated means, as determined by empirical formulae, for the 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, show a fairly close agreement with the corresponding observed averages. The average weighted absolute deviations range from about 0.5 to about 0.7 mm, and the corresponding percentage deviations fall between 2.0 and 2.5.

This dimension does not seem to have been previously measured in fetal life. Le Damany, studying this or a similar dimension in a series of 200 living, newborn children, obtained an average of 8.81 cm for males (average crown-heel length 49.3 cm) and 8.89 cm for females (average crown-heel length 49.2 cm). Our natal value, as computed by the graphic formula (at 50.2 cm crown-heel length), is 7.4 cm.

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* The plan used in preparing the following summaries is described in Part I, Section IV (p. 54) of this monograph.

TABLE 106

HEIGHT OF PELVIS (CREST OF ILIUM TO RUMP)
.155 CH (MM.) - 4.0MM. (245 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Height of Pelvis (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		C H Length (cm.)	Value (mm)	Per cent. increment
23-50	37.3	31.6	6.5	2.5	4.8	1.8	-3.0	-62.5	12	5	3.75	—
50-100	75.6	57.1	12	5	8.6	7.7	-0.9	-10.5	22	10	11.50	207
100-150	123.8	88.4	20	10	15.0	15.2	+0.2	+ 1.3	30	15	19.25	67
150-200	172.3	119.0	28	19	22.0	22.7	+0.7	+ 3.2	22	20	27.00	40
200-250	226.3	153.2	36	23	30.8	31.1	+0.3	+ 1.0	30	25	34.75	29
250-300	272.9	183.8	43	32	38.0	38.3	+0.3	+ 0.8	21	30	42.50	22
300-350	326.7	220.1	52	38	45.6	46.6	+1.0	+ 2.2	29	35	50.25	18
350-400	372.0	250.6	64	41	52.5	53.7	+1.2	+ 2.3	25	40	58.00	15
400-450	422.6	288.2	69	52	60.2	61.5	+1.3	+ 2.2	19	45	65.75	13
450-500	474.3	322.2	76	60	70.2	69.5	-0.7	- 1.0	18	50	73.50	12
500-544	525.1	362.9	91	65	77.6	77.4	-0.2	- 0.3	17	55	81.25	10

50. Interspinous Diameter of Pelvis

(Field Graph 50, Tables 107 and 108)

The interspinous diameter of the pelvis was measured as a straight line between the lateral surfaces of the two anterior superior iliac spines. The measurement was made with points of the calipers pressed firmly against the skeletal points in question. The interspinous diameter is raised less than one-half of 1 per cent by injection, but subsequent immersion in formalin increases the dimension approximately 3 per cent.

Table 107 summarizes our findings for this diameter. The calculated values, as determined by empirical formulae, for 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, show average departures of less than 1 mm and of 2 per cent or less from the corresponding observed means for these intervals. Most of this error lies in the correction for the effects of injection and preservation in the last two 5 cm intervals of the progression.

So far as we are aware, there are no published data on the growth of the interspinous diameter in the fetal period. But a number of studies of the growth of the pelvis in postnatal life include measurements of the diameter in the newborn. The more important averages for the newborn are listed in table 108, together with our calculated natal value (as obtained by the graphic empirical formula).

TABLE 107

INTERSPINOUS DIAMETER OF PELVIS
.145 CH (MM.) - 2.5 MM. (245 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Interspinous Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min	Mean (a)	Mean (b)	mm.	Per cent.				
23-50	37.3	31.6	6	3	4.8	2.9	-1.9	-39.6	12	5	4.75	—
50-100	76.4	57.7	11	5	8.5	8.6	+0.1	+1.2	23	10	12.00	153
100-150	123.8	88.4	20	11.5	15.4	15.5	+0.1	+0.6	30	15	19.25	60
150-200	172.3	119.0	28	19	22.4	22.5	-0.1	+0.4	22	20	26.50	38
200-250	225.9	153.1	36	25	29.8	30.3	+0.5	+1.7	29	25	33.75	27
250-300	272.9	183.8	45	32	37.4	37.1	-0.3	-0.8	21	30	41.00	21
300-350	326.7	220.1	51	38	44.8	44.9	+0.1	+0.2	29	35	48.25	18
350-400	372.0	250.6	58	43	50.7	51.4	+0.7	+1.4	25	40	55.50	15
400-450	422.6	288.2	67	51	58.1	58.8	+0.7	+1.2	19	45	62.75	13
450-500	474.3	322.2	81	62	69.7	66.3	-3.4	-4.9	18	50	70.00	12
500-544	525.1	362.9	88	71	76.9	73.6	-3.3	-4.3	17	55	77.25	10

TABLE 108

AVERAGE INTERSPINOUS DIAMETER OF THE PELVIS AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE INTERSPINOUS DIAMETER (cm)
Klein (males)	....	6.86
Klein (females)	....	7.38
Konikow (males)	....	6.83
Konikow (females)	....	6.33
Tatewossoff (males)	51.9	7.20
Tatewossoff (females)	51.7	7.05
Present series (calculated)	50.2	7.03

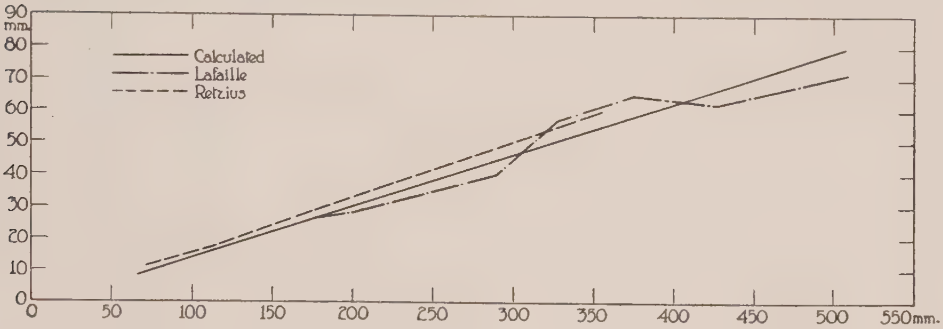
51. Intercristal Diameter of Pelvis

(Figure 48, Field Graph 51, Tables 109, 110, and 176)

The intercristal diameter of the pelvis was measured as a straight line, in the transverse plane of the body, between the most lateral extensions of the iliac crests. The technique of measurement was similar to that employed for the interspinous diameter. This dimen-

FIGURE 48

THE GROWTH OF THE INTERCRISTAL DIAMETER OF THE PELVIS IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Intercristal diameter of pelvis (mm).

TABLE 109

INTERCRISTAL DIAMETER OF PELVIS
.1625 CH(MM.) - 2.5 MM. (246 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Intercristal Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent		C.H. Length (cm.)	Value (mm.)	Per cent. increment
23-50	37.3	31.6	7	3	5.2	3.6	-1.6	-30.8	12	5	5.625	—
50-100	76.4	57.7	13	6	9.7	9.9	+0.2	+2.1	23	10	13.750	144
100-150	123.8	88.4	21	13	16.6	17.6	+1.0	+6.0	30	15	21.875	59
150-200	172.3	119.0	32	22	24.9	25.5	+0.6	+2.4	22	20	30.000	37
200-250	226.3	153.2	40	27	33.2	34.3	+1.1	+3.3	30	25	38.125	27
250-300	272.9	183.8	50	38	41.8	41.8	±0.0	±0.0	21	30	46.250	21
300-350	326.7	220.1	58	44	50.7	50.6	-0.1	-0.2	29	35	54.375	18
350-400	372.0	250.6	68	48	57.8	58.0	+0.2	+0.3	25	40	62.500	15
400-450	422.6	288.2	75	59	66.4	66.2	-0.2	-0.3	19	45	70.625	13
450-500	474.3	322.2	91	72	78.6	74.6	-4.0	-5.1	18	50	78.750	12
500-544	525.1	362.9	98	78	88.2	82.8	-5.4	-6.1	17	55	86.875	10

sion is increased approximately 3 per cent by injection and this increase rises to 7.2 per cent after three months' preservation in formalin. It then undergoes a decrease to 5.9 per cent at the end of six months' preservation.

TABLE 110

AVERAGE INTERCRISTAL DIAMETER OF THE PELVIS AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE INTERCRISTAL DIAMETER (cm)
De Lee	....	9.0
Hirst	....	9.5
Klein (males)	....	8.08
Klein (females)	....	7.36
Konikow (males)	....	7.5
Konikow (females)	....	7.16
Le Damany (males)	49.3	9.8
Le Damany (females)	49.0	9.7
Quetelet (males)	50.0	7.9
Quetelet (females)	49.4	7.8
Tatewossoff (males)	51.9	7.95
Tatewossoff (females)	51.7	7.8
Taylor (males)	51.2	8.0
Taylor (females)	50.0	7.8
Weissenberg (males)	50.8	7.8
Weissenberg (females)	50.0	7.7
Present series (calculated)	50.2	7.9

Our summarized findings for this dimension are given in table 109. The average absolute deviations of the calculated from the observed values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 0.9 to about 1.3 mm. The corresponding relative deviations range from about 2 to 2.5 per cent. As in the case of the interspinous diameter, these deviations are greatest in the last two 5 cm intervals of the distribution, and are due mainly to the correction for formalin injection and preservation.

The data on this dimension in the fetal period have been published by Lafaille and by Retzius. Our findings give values that are slightly below those of the latter author, while Lafaille's averages show greater irregularity, as will be seen by the curve of his data in figure 48. There are considerable data on the value of the intercristal diameter at birth. The averages of the chief series of observations are given in table 110.

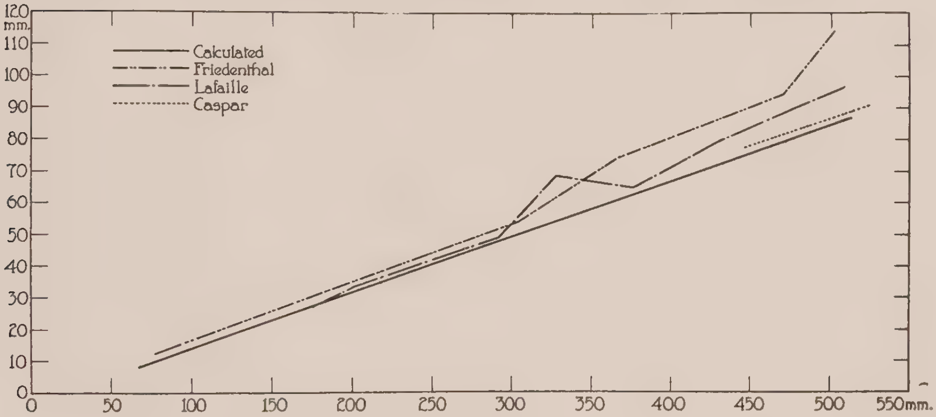
52. Intertrochanteric Diameter of Pelvis

(Figure 49, Field Graph 52, Tables 111, 112, and 176)

This dimension represents the distance between the lateral surfaces of the greater trochanters with the thighs moderately adducted. We were surprised to find that the experimental error in determining this diameter was relatively small. This dimension is increased 1.3 per cent by injection and continues to increase during subsequent preservation in formalin. The correction figure after six months' immersion is −2.8 per cent.

FIGURE 49

The Growth of the Intertrochanteric Diameter of the Pelvis in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Intertrochanteric diameter of pelvis (mm).

Table 111 summarizes our findings for the intertrochanteric diameter. The calculated values of the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average deviations ranging from about 1.5 to 2.5 mm from the corresponding observed means. The corresponding average relative deviations range from about 2.7 to about 3.8 per cent. The greatest deviations are found in the fifth and the last two 5 cm intervals. Those of the last two intervals seem due mainly to correction for formalin artifacts.

The growth of the intertrochanteric diameter in the fetal period has been previously studied by Caspar, Friedenthal, and Lafaille. Our findings are in quite close agreement with those of Lafaille and of

Caspar. Friedenthal's averages are distinctly above those of all other observers. The available data on this dimension in the newborn are summarized in table 112.

TABLE 111

INTERTROCHANTERIC DIAMETER OF PELVIS
.1775 CH (MM.) – 3.5 MM. (244 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Intertrochanteric Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Percent.		C H Length (cm)	Value (mm)	Per cent. increment
23-50	37.3	31.6	7.5	3.5	5.3	3.1	-2.2	-41.5	10	5	5.375	—
50-100	76.4	57.7	14	6	9.9	10.1	+0.2	+2.0	19	10	14.250	165
100-150	124.6	88.9	22	13	17.9	18.6	+0.7	+3.9	29	15	23.125	62
150-200	172.3	119.0	34	23	26.5	27.1	+0.6	+2.3	19	20	32.000	38
200-250	225.9	153.1	42	29	34.7	36.6	+1.9	+5.5	23	25	40.875	28
250-300	272.9	183.8	53	40	44.8	44.9	+0.1	+0.2	21	30	49.750	22
300-350	326.7	220.1	62	47	54.7	54.5	-0.2	-0.4	28	35	58.625	18
350-400	372.0	250.6	76	51	62.3	62.5	+0.2	+0.3	22	40	67.500	15
400-450	422.6	288.2	83	63	72.4	71.5	-0.9	-1.2	19	45	76.375	13
450-500	474.3	322.2	97	79	86.7	80.7	-6.0	-6.9	18	50	85.250	12
500-544	525.1	362.9	112	86	97.6	89.7	-7.9	-8.1	17	55	94.125	10

TABLE 112

AVERAGE INTERTROCHANTERIC DIAMETER OF THE PELVIS AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE INTERTROCHANTERIC DIAMETER (cm)
Edgar	....	9.0
Klein (males)	....	9.25
Klein (females)	....	9.58
Konikow (males)	....	9.0
Konikow (females)	....	8.72
Quetelet (males)	50.0	10.5
Quetelet (females)	49.4	10.4
Tatewossoff (males)	51.9	9.2
Tatewossoff (females)	51.7	9.05
Taylor (males)	51.2	9.1
Taylor (females)	50.0	8.9
Webster	....	9.0
Present series (calculated)	50.2	8.6

53. External Conjugate Diameter of Pelvis (Diameter of Baudelocque)

(Field Graph 53, Tables 113 and 114)

This dimension was measured from the superficial tissues over the inferior margin of the symphysis pubis to the space between the last lumbar and first sacral vertebra. Considerable difficulty was encountered in determining these points with accuracy. The external conjugate diameter is increased 22.2 per cent with injection. After six months' subsequent preservation in formalin the value in preserved material is 22.4 per cent greater than in fresh specimens.

TABLE 113

External Conjugate Diameter of Pelvis
.115 CH(mm.)-1.0 mm.(237 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	External Conjugate Diameter (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max	Min.	Mean (a)		mm.	Per cent.		C H Length (cm)	Value (mm)	Per cent. increment
23-50	39.8	33.5	6	3.5	4.5	3.6	-0.9	-20.0	10	5	4.75	—
50-100	76.4	57.6	10	4.5	7.6	7.8	+0.2	+2.6	22	10	10.50	121
100-150	123.8	88.4	16	9.5	12.4	13.2	+0.8	+6.5	30	15	16.25	55
150-200	172.3	119.0	23	14.5	18.6	18.8	+0.2	+1.1	22	20	22.00	35
200-250	225.5	152.9	30	20	24.7	24.9	+0.2	+0.8	28	25	27.75	26
250-300	272.9	183.8	38	26	30.4	30.4	±0.0	±0.0	21	30	33.50	21
300-350	327.3	220.6	42	29	36.3	36.6	+0.3	+0.8	28	35	39.25	17
350-400	372.1	249.5	49	36	41.9	41.8	-0.1	-0.2	22	40	45.00	15
400-450	422.6	288.2	57	41	51.3	47.6	-3.7	-7.2	19	45	50.75	13
450-500	474.3	322.2	71	54	61.8	53.5	-8.3	-13.4	18	50	56.00	11
500-544	525.1	362.9	72	57	63.8	59.4	-4.4	-6.9	17	55	61.75	9

Table 113 summarizes our findings for this dimension. Despite the large errors introduced by the difficulties of measurement and by formalin artifacts, the agreement of our calculated and observed values for the external conjugate diameter is fairly satisfactory. The calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations of 1.5 to 2.0 mm, and relative deviations of 3.6 to over 5 per cent, from the corresponding observed averages.

We have found no published observations on this diameter in the fetal period. There are, however, several sets of observations on the natal value that are summarized in table 114.

TABLE 114

Average External Conjugate Diameter of the Pelvis at Birth

Observer	Average body-length (cm)	Average conjugate diameter (cm)
Edgar	....	5.5
Klein (males)	....	6.0
Klein (females)	....	5.63
Konikow (males)	....	7.0
Konikow (females)	....	6.33
Tatewossoff (males)	51.9	6.85
Tatewossoff (females)	51.7	6.95
Present series (calculated)	50.2	5.62

54. Bi-Tuberous Distance of Pelvis

(Field Graph 54, Table 115)

This dimension represents the distance between the internal margins of the ischial tuberosities. These points were determined by inserting fine steel stylets through the superficial tissues to the bony landmarks. There is considerable error in making these determina-

TABLE 115

Bi-Tuberous Distance of Pelvis
.04C H(mm.) ± 0.0mm. (231 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Bi-tuberous Distance (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min	Mean(a)		mm.	Percent		C H Length (cm.)	Value (mm.)	Percent increment
23-50	41.0	34.0	—	—	2.5	1.6	-0.9	-36.0	1	5	2.0	—
50-100	75.6	57.1	6	1	3.6	3.0	-0.6	-16.7	22	10	4.0	100
100-150	123.8	88.4	7	3	4.1	4.9	+0.8	+19.5	30	15	6.0	50
150-200	172.3	119.0	7	4	5.8	6.9	+1.1	+19.0	22	20	8.0	33
200-250	225.5	152.9	12	5	8.6	9.0	+0.4	+4.7	28	25	10.0	25
250-300	272.9	183.8	13	8	10.0	10.9	+0.9	+9.0	21	30	12.0	20
300-350	326.7	220.1	17	9	12.2	13.1	+0.9	+7.4	29	35	14.0	17
350-400	372.0	250.6	20	13	15.2	14.9	-0.3	-2.0	25	40	16.0	14
400-450	422.6	288.0	24	13	18.4	16.9	-1.5	-8.2	19	45	18.0	12
450-500	474.3	322.2	28	17	22.3	19.0	-3.3	-14.8	18	50	20.0	11
500-544	526.8	363.0	30	23	26.0	21.1	-4.9	-18.8	16	55	22.0	10

tions, both because of the difficulty in locating the exact landmarks, and because of the smallness of the dimension in the younger fetuses. The bi-tuberous distance is apparently increased 7.6 per cent by injection. Following injection there is a steady decrease of this dimension with preservation in formalin until the values at the end of six months' average 2.3 per cent less than in fresh material.

Table 115 summarizes our findings for this dimension. Our calculated values, as determined by empirical formulae, show average absolute deviations of 1.11 to 1.63 mm from the corresponding observed 5 cm interval averages from 5 to 55 cm of crown-heel length, inclusive. The root mean square deviations range from 1.3 to 2.0 mm. The mean relative deviations are highly variable, ranging from about 10 per cent to over 13 per cent.

We have found no published observations of this dimension in the fetus or newborn. Our calculated natal value (at 50.2 cm crown-heel length) is 2.0 cm.

III. Résumé and Discussion of Findings on the External Dimensions of the Pelvis

The empirical formulae (as determined by graphic methods) for the external dimensions of the pelvis all show negative secondary or *b* constants with the exception of that for the bi-tuberous distance where the secondary constant is zero. The calculated values for these dimensions at each 5 cm interval of crown-heel length from 5 to 50 cm, inclusive, are shown in table 116 and represented graphically in figure 50.

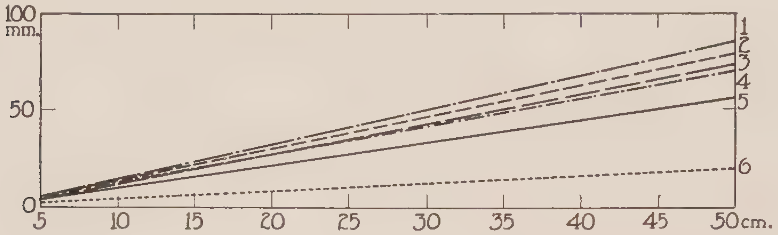
TABLE 116

CALCULATED VALUES OF THE EXTERNAL DIMENSIONS OF THE PELVIS AT EACH FIVE-CENTIMETER INTERVAL OF CROWN-HEEL LENGTH

Dimension	Formulae		Calculated values (mm.) at crown-heel lengths of:									
	a	b	5cm.	10cm.	15cm.	20cm.	25cm.	30cm.	35cm.	40cm.	45cm.	50cm.
Iliac crest to rump (pelvis height)	.155	-4.0	3.8	11.5	19.3	27.0	34.8	42.5	50.3	58.0	65.8	73.5
Interspinous diameter	.145	-2.5	4.8	12.0	19.3	26.5	33.8	41.0	48.3	55.5	62.8	70.0
Intercristal diameter	.1625	-2.5	5.6	13.8	21.9	30.0	38.1	46.3	54.4	62.5	70.6	78.8
Intertrochanteric diameter	.1775	-3.5	5.4	14.3	23.1	32.0	40.9	49.8	58.6	67.5	76.4	85.3
External conjugate diameter	.115	-1.0	4.8	10.5	16.3	22.0	27.8	33.5	39.3	45.0	50.8	56.5
Bi-tuberous distance	.04	±0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0

FIGURE 50

The Growth of the External Dimensions of the Pelvis (as Determined by Empirical Formulae) in the Fetal Period with Respect to Growth in Crown-Heel Length



Abscissa: Crown-heel length (cm). Ordinates: External dimensions of the pelvis (mm).

1. Intertrochanteric diameter
2. Intercristal diameter
3. Distance from iliac crest to rump (pelvis height)
4. Interspinous diameter
5. External conjugate diameter
6. Bi-tuberous distance

Table 117 and figure 51 show the calculated values of these dimensions at the close of each month of the fetal period from three to ten months, inclusive. The computed absolute and percentage increments of these dimensions for each 5 cm interval of total body-length are given in connection with the detail tables for individual dimensions (tables 106, 107, 109, 111, 113, and 115).

TABLE 117

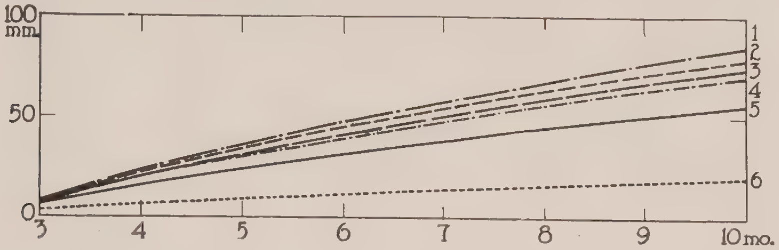
Calculated Values of the External Dimensions of the Pelvis at the Close of Each Month of the Fetal Period

Dimension	Formulae		Calculated values (mm.) at:							
	a	b	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Iliac crest to rump (pelvis height)	.155	-4.0	7.0	20.1	31.3	41.3	50.3	58.7	66.5	73.8
Interspinous diameter	.145	-2.5	8.8	20.0	30.5	39.8	48.3	56.1	63.4	70.3
Intercristal diameter	.1625	-2.5	9.0	22.8	34.5	45.0	54.5	63.2	71.4	79.1
Intertrochanteric diameter	.1775	-3.5	9.1	24.1	37.0	48.3	58.7	68.3	77.2	85.6
External conjugate diameter	.115	-1.5	6.6	16.4	24.7	32.1	38.8	45.0	50.8	56.2
Bi-tuberous distance	.04	±0.0	2.8	6.2	9.1	11.7	14.0	16.2	18.2	20.1

Tables 118 and 119 present the calculated monthly absolute and percentage increments in the pelvic dimensions. The absolute increments in the fourth fetal month range from 3.4 mm for the bi-tuberous distance to 15.0 mm for the intertrochanteric diameter. In the seventh month this range falls between 2.3 mm for the bi-tuberous

FIGURE 51

The Growth of the External Dimensions of the Pelvis (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: External dimensions of the pelvis (mm).

1. Intertrochanteric diameter
2. Intercristal diameter
3. Distance from iliac crest to rump (pelvis height)
4. Interspinous diameter
5. External conjugate diameter
6. Bi-tuberous distance

distance and 10.4 mm for the intertrochanteric diameter. In the tenth month the increments range from 1.9 mm for the bi-tuberous distance to 8.4 mm for the intertrochanteric diameter.

TABLE 118

Calculated Absolute Increments of the External Dimensions of the Pelvis in Each Month of the Fetal Period

Dimension	Absolute increments (mm.) in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Iliac crest to rump (pelvis height)	13.1	11.2	9.9	9.1	8.3	7.8	7.3
Interspinous diameter	12.3	10.5	9.3	8.5	7.8	7.3	6.9
Intercristal diameter	13.7	11.8	10.4	9.5	8.7	8.2	7.7
Intertrochanteric diameter	15.0	12.9	11.4	10.4	9.5	8.9	8.4
External conjugate diameter	9.7	8.3	7.4	6.7	6.2	5.8	5.4
Bi-tuberous distance	3.4	2.9	2.6	2.3	2.2	2.0	1.9

The percentage increments of the pelvic dimensions are relatively large in the fourth month, ranging from 121.4 per cent for the bi-tuberous distance, to 187.1 per cent for the pelvic height. These increments decrease very rapidly and the relative gain of all the pelvic dimensions in the seventh month ranges from 20 to 22 per cent. By the tenth month the percentage increment has declined to 10.4 per cent, in the case of the bi-tuberous distance, and to 11 per cent,

TABLE 119

Calculated Percentage Increments of the External Dimensions of the Pelvis in Each Month of the Fetal Period

Dimension	Percentage increments in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Iliac crest to rump (pelvis height)	187.1	55.7	31.6	22.0	16.5	13.3	11.0
Interspinous diameter	139.8	52.5	30.5	21.4	16.1	13.0	10.9
Intercristal diameter	152.2	51.8	30.1	21.1	16.0	13.0	10.8
Intertrochanteric diameter	164.8	53.5	30.8	21.5	16.2	13.0	10.9
External conjugate diameter	147.0	50.6	30.0	20.9	16.0	12.9	10.6
Bi-tuberous distance	121.4	46.7	28.1	20.0	15.3	12.5	10.4

in the case of the pelvic height. In the last month of the fetal period the pelvic diameters show a gain ranging from 10.6 to 10.9 per cent.

The percentage of natal value attained by each dimension at each 5 cm interval of total or crown-heel body-length is shown in table 120. At 5 cm crown-heel length the greatest value is that of the bi-tuberous distance which is 10 per cent, and the least is that of the pelvic height which is 5.2 per cent. At 25 cm crown-heel length most of the pelvic dimensions have attained a little less than one-half of their natal size, although the bi-tuberous distance has acquired an even 50 per cent of its total prenatal growth.

TABLE 120

Per Cent of Natal Value Attained by Each External Dimension of the Pelvis at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Percentage of natal value at crown-heel lengths of:									
	5cm.	10cm.	15cm.	20cm.	25cm.	30cm.	35cm.	40cm.	45cm.	50cm.
Iliac crest to rump (pelvis height)	5.2	15.6	26.3	36.7	47.4	57.9	68.4	79.2	89.5	100.0
Interspinous diameter	6.8	17.1	27.6	37.9	48.3	58.6	69.0	79.3	89.7	100.0
Intercristal diameter	7.1	17.5	27.8	38.1	48.4	58.8	69.0	79.3	89.6	100.0
Intertrochanteric diameter	6.3	16.8	27.1	37.5	47.9	58.4	68.7	79.1	89.6	100.0
External conjugate diameter	8.5	18.6	28.8	38.9	49.2	59.3	69.6	79.6	89.9	100.0
Bi-tuberous distance	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0

The percentages of natal values attained by the various dimensions at each fetal month are shown in table 121. At three months the pelvic height is 9.5 per cent of its birth value, and the bi-tuberous distance is 14.1 per cent. The various diameters of the pelvis have

TABLE 121

Per Cent of Natal Value Attained by Each External Dimension of the Pelvis at the Close of Each Month of the Fetal Period

Dimension	Percentage of natal value at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Iliac crest to rump (pelvis height)	9.5	27.2	42.4	56.0	68.2	79.5	90.1	100.0
Interspinous diameter	12.5	28.4	43.4	56.6	68.7	79.8	90.2	100.0
Intercristal diameter	11.4	28.8	43.6	56.9	68.9	79.9	90.3	100.0
Intertrochanteric diameter	10.6	28.2	43.2	56.4	68.6	79.8	90.2	100.0
External conjugate diameter	11.7	29.2	44.0	56.9	69.0	80.1	90.4	100.0
Bi-tuberous distance	14.1	31.0	45.4	58.2	69.8	80.5	90.5	100.0

attained from 10.6 to 12.5 per cent of their natal size at this time. At six months all of the dimensions have completed over half of their prenatal growth, the range being from 56.0 per cent for the pelvic height, to 58.2 per cent for the bi-tuberous distance. At nine months all of the pelvic dimensions are approximately nine-tenths of their size in the newborn, the range being from 90.1 per cent for the pelvic height to 90.5 per cent for the bi-tuberous distance.

Tables 122 and 123 show the relative size of the pelvic dimensions at various intervals of crown-heel length and of fetal age. At 5 cm crown-heel length the computed pelvic diameters are equivalent to approximately one-tenth of the body-length, varying from 9.6 per cent for the external conjugate diameter to 11.2 per cent for the intercristal diameter. At this stage the pelvic height is equal to 7.6 per

TABLE 122

Relative Size of the External Dimensions of the Pelvis (Computed as Per Cents of the Crown-Heel Length) at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Per cent of total (crown-heel) length at:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Iliac crest to rump (pelvis height)	7.6	11.5	12.9	13.5	13.9	14.2	14.4	14.5	14.6	14.6
Interspinous diameter	10.6	12.0	12.9	13.3	13.5	13.7	13.8	13.9	14.0	14.0
Intercristal diameter	11.2	13.8	14.6	15.0	15.2	15.4	15.5	15.6	15.7	15.8
Intertrochanteric diameter	10.8	14.3	15.4	16.0	16.4	16.6	16.7	16.9	17.0	17.1
External conjugate diameter	9.6	10.5	10.9	11.0	11.1	11.2	11.2	11.3	11.3	11.3
Bi-tuberous distance	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

cent and the bi-tuberous distance to 4 per cent of the crown-heel length. At 25 cm crown-heel length the various computed pelvic diameters are equal to 11.1 to 16.4 per cent of the standing-height, the external conjugate diameter having the least, and the intertrochanteric diameter, the greatest, relative size. At this stage the pelvic height is equivalent to 13.9 per cent and the bi-tuberous distance to 4 per cent of the crown-heel length. At 50 cm the external conjugate diameter of the pelvis is equivalent to 11.3 per cent of the total body-length and the intertrochanteric diameter to 17.1 per cent,

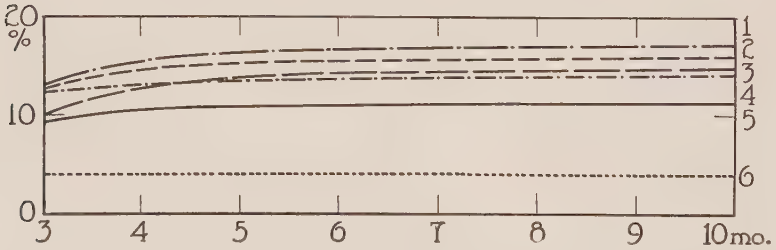
TABLE 123

Relative Size of the External Dimensions of the Pelvis (Computed as Per Cents of the Crown-Heel Length) at the Close of Each Month of the Fetal Period

Dimension	Per cent. of total (crown-heel) length at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Iliac crest to rump (pelvis height)	9.9	12.9	13.7	14.1	14.4	14.5	14.6	14.7
Interspinous diameter	12.4	12.9	13.4	13.6	13.8	13.9	13.9	14.0
Intercristal diameter	12.7	14.7	15.1	15.4	15.5	15.6	15.7	15.8
Intertrochanteric diameter	12.9	15.5	16.2	16.5	16.7	16.9	17.0	17.1
External conjugate diameter	9.3	10.6	10.8	11.0	11.1	11.1	11.2	11.2
Bi-tuberous distance	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

FIGURE 52

The Changes in the Relative Size of the External Dimensions of the Pelvis in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the external dimensions of the pelvis expressed as per cents of the crown-heel length.

1. Intertrochanteric diameter
2. Intercristal diameter
3. Distance from iliac crest to rump (pelvis height)
4. Interspinous diameter
5. External conjugate diameter
6. Bi-tuberous distance

while the interspinous and intercristal are intermediate to these two. At this stage the pelvic height approximates 14.6 per cent of the body-length, and the bi-tuberous distance remains at 4 per cent.

At three fetal months the computed transverse diameters of the pelvis are equivalent to between 12 and 13 per cent of the body-length and these values rise to 14 and 17.1 per cent at birth. The computed external conjugate diameter rises from 9.3 to 11.2 per cent in this period, and the pelvic height from 9.9 to 14.7 per cent. The computed relative value for the bi-tuberous distance remains constant at 4 per cent throughout the fetal period.

A comparison of the breadths of the shoulders and the pelvis may be made by computing the acromio-cristal index by dividing the computed intercristal diameter of the pelvis by the computed bi-acromial diameter and multiplying the result by 100. The figures thus obtained are 49.6 at 5 cm crown-heel length, 67.7 at 25 cm, and 70.0 at 50 cm; and 56.6 at three fetal months, 68.5 at six months, and 70.0 at ten months or birth. Another index may be computed by dividing the intertrochanteric diameter by the bi-acromial and multiplying by 100. This index is 47.8 at 5 cm crown-heel length, 72.6 at 25 cm, and 75.8 at 50 cm; and 57.2 at three fetal months, 73.5 at six months, and 75.8 at ten months or birth. Thus the breadth of the pelvic girdle, as indicated by these measures, is increasing much more rapidly than that of the shoulder girdle. Schultz has made a comparison of the bi-acromial width with "width between the hips" and he also found this relatively greater increase in the pelvic width; however, his figures for the index are much higher than ours, being 58 per cent in white fetuses of nine weeks and 84 per cent at birth.

We have made a series of inter-pelvic indices by determining the percentages that certain of the larger dimensions form of the intercristal diameter. According to these computations the interspinous diameter forms 85.7 per cent of the intercristal diameter at 5 cm crown-heel length, 88.7 at 25 cm, and 88.8 at 50 cm; and 86.7 per cent at three fetal months, 88.4 at six months, and 88.9 at ten months or birth. The intertrochanteric diameter forms 96.4 per cent of the intercristal diameter at 5 cm crown-heel length, 107.3 at 25 cm, and 108.2 at 50 cm; and 101.1 per cent at three fetal months, 107.3 at six months, and 108.2 at ten months or birth. Thus the interspinous diameter of the pelvis is growing slightly more rapidly, and the intertrochanteric diameter much more rapidly, than the intercristal diameter.

At 5 cm crown-heel length the pelvic height forms 67.9 per cent of the intercristal diameter, at 25 cm 91.3 per cent, and at 50 cm 93.3 per cent. At three fetal months the percentage is 77.8, at six months, 91.8, and at ten months, 93.3. These figures indicate that the pelvis is growing distinctly more rapidly in height than in breadth in the fetal period.

The external conjugate diameter forms 87.5 per cent of the intercristal diameter at 5 cm crown-heel length, 73.0 at 25 cm, and 71.7 at 50 cm; and 78.9 at three fetal months, 72.4 at six months, and 71.7 at ten months or birth. These percentages indicate that in the fetal period the antero-posterior diameter of the pelvis is growing more slowly than the breadth.

PART VII

SUMMARY OF FINDINGS ON THE EXTERNAL DIMENSIONS OF THE UPPER EXTREMITY

I. Introductory Note

The growth of the upper extremity was studied on the basis of measurements of 8 dimensions. Five of these dimensions were linear measurements: length of the upper extremity as a whole, length of the arm, length of the forearm, length of the hand, and length of the median finger. The length of the entire extremity was obtained by adding the lengths of the arm, forearm, and hand. The remaining three measurements were circumferences of the limbs at the level of the maximum girth of the arm, the level of the maximum girth of the forearm, and at the level of the wrist just proximal to the thenar and hypothenar eminences. All of the measurements were made of the right limbs only. Other dimensions that involve a portion of the upper extremity are considered with the trunk in Part V of this monograph. These are the bi-acromial distance, the bi-deltoid circumference, and the bi-deltoid diameter.

II. Consideration of Individual Dimensions*

55. Upper Extremity Length

(Figure 53, Field Graph 55, Tables 124, 125, 177, and 180)

The length of the upper extremity is commonly defined as the distance in a straight line from the lateral tip of the acromial process to the end of the middle finger. Since the specimens in our series were usually flexed, the measurement of the superior extremity herein recorded consists of the sum of the distances from the acromial process to the angle of the elbow, from the angle of the elbow to the base of the palm of the hand, and from the base of the palm of the hand to the tip of the middle finger.

Our experimental study shows no evidence of any change of the length of the upper extremity as a result of injection. Subsequent preservation in formalin causes a slight decrease, amounting to 0.3 per cent at six months.

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* The plan used in preparing the following summaries is described in Part I, Section IV (p. 54) of this monograph.

TABLE 124

UPPER EXTREMITY LENGTH (ACROMION TO TIP OF MIDDLE FINGER)
.4 C.H.LENGTH−4.0MM. (314 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm.)	Upper Extremity Length				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm Intervals of Crown Heel Length		
			Observed			(b) Calculated						
Range	Mean		Max.	Min	Mean (a)		mm	Percent.		C H Length (cm)	Value (mm)	Per cent increment
23-50	35.4	30.3	17	6	10.4	10.2	-0.2	-1.9	12	5	16.0	—
50-100	75.3	56.9	34	16	25.4	26.1	+0.7	+2.8	25	10	36.0	125
100-150	124.8	88.7	55	35	45.4	45.9	+0.5	+1.1	42	15	56.0	56
150-200	172.5	118.9	79	51	64.9	64.9	±0.0	±0.0	26	20	76.0	36
200-250	224.5	151.7	106	72	88.0	85.8	-2.2	-2.5	47	25	96.0	26
250-300	271.4	182.0	123	87	105.5	104.6	-0.9	-0.9	42	30	116.0	21
300-350	326.4	220.3	155	107	127.3	126.6	-0.7	-0.5	32	35	136.0	17
350-400	370.2	249.2	159	134	145.1	144.1	-1.0	-0.7	30	40	156.0	15
400-450	421.2	286.4	178	148	164.9	164.5	-0.4	-0.2	17	45	176.0	13
450-500	473.4	321.5	202	170	186.5	185.4	-1.1	-0.6	23	50	196.0	11
500-544	525.1	361.5	217	192	202.8	206.0	+3.2	+1.6	23	55	216.0	10

TABLE 125

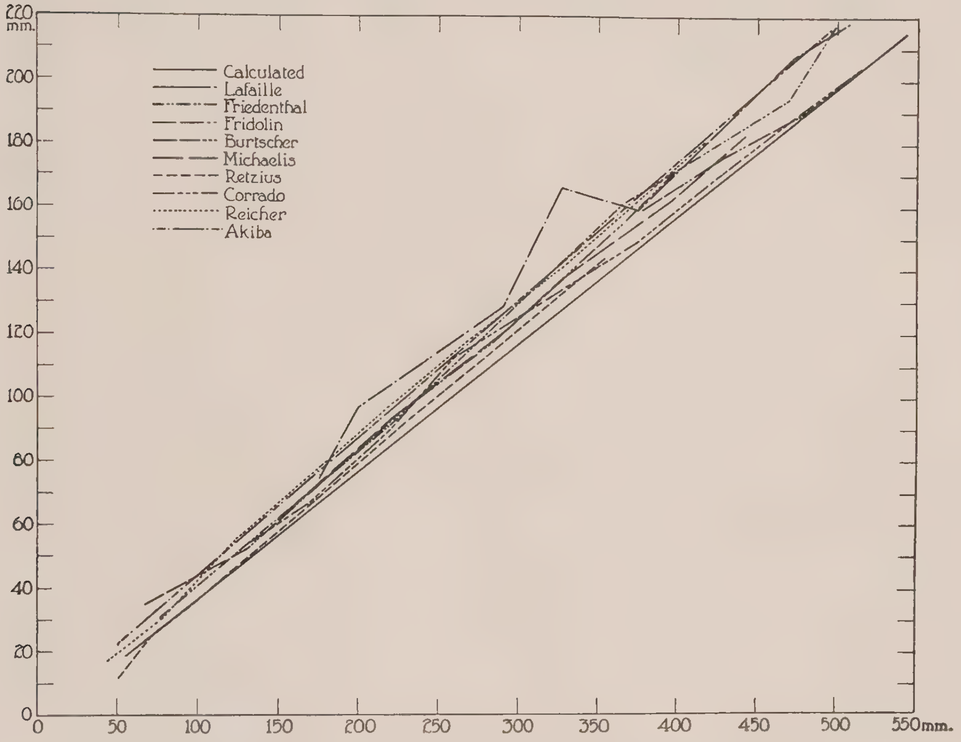
AVERAGE LENGTH OF THE UPPER EXTREMITY AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE LENGTH OF UPPER EXTREMITY (cm)
Meeh (males)	55.0	21.0
Meeh (females)	50.0	20.0
Orchansky (males)	49.52	20.3
Orchansky (females)	48.3	19.75
Quetelet (males)	50.0	20.6
Quetelet (females)	49.4	20.4
Reicher (males)	49.2	21.69
Reicher (females)	50.0	21.39
Schadow	48.6	23.4
Taylor (males)	51.2	20.3
Taylor (females)	50.0	19.7
Weissenberg (males)	50.8	21.4
Weissenberg (females)	50.0	21.0
Zeising	....	20.1
Present series (calculated)	50.2	19.7

Table 124 summarizes our findings and computations for this dimension. Our calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations of less than 1.2 mm from the corresponding observed values. The corresponding average percentage deviations range between 1.1 and 1.5 per cent.

FIGURE 53

The Growth of the Length of the Upper Extremity in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Length of upper extremity (mm).

The growth in length of the upper extremity in the fetal period has been previously studied by Lafaille, Friedenthal, Fridolin, Burtscher, Michaelis, Retzius, Corrado, Reicher, Schultz, and others. Some of these observations are given in tables 177 and 180 and in figure 53. Most of these observations, with the exception of those of Lafaille, which are extremely irregular, show the same central tendency as do our findings. Our calculated values are slightly lower than most of them, although they approximate those of Retzius and of Corrado.

There are a considerable number of observations upon the length of the upper extremity in the newborn. The more important of these, together with our calculated natal value, are given in table 125.

56. Length of Arm (Acromion to Elbow)

(Figure 54, Field Graph 57, Tables 126, 127, and 178)

The length of the arm was determined as a straight line from the tip of the acromial process to the middle of the cubital fossa. This point is generally marked by a fold a little above the level of the joint. No determination was made of the injection or fixation error in this dimension. This error is no doubt negligible, for the upper extremity as a whole shows no change on injection, and only 0.3 per cent change after six months' subsequent preservation in formalin.

TABLE 126

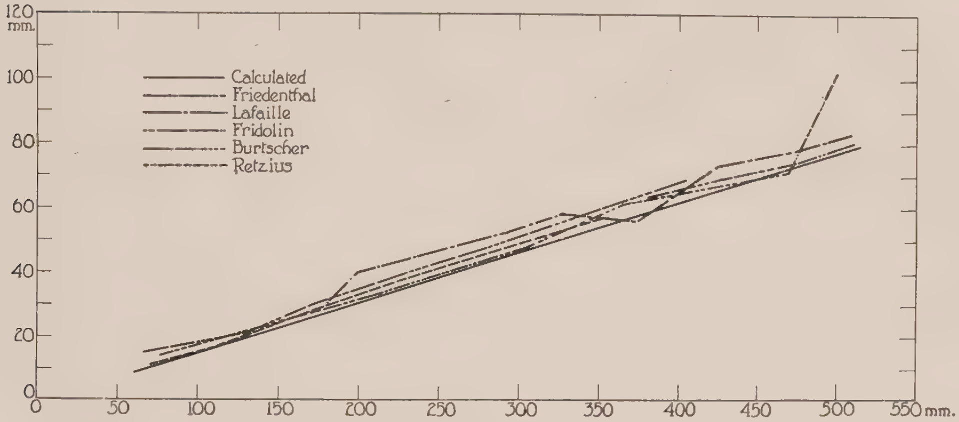
LENGTH OF ARM (ACROMION TO ELBOW)
.155 CH (MM.) - 0.5 MM. (307 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Length of Arm (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	41.0	34.0	—	—	6.5	5.9	-0.6	-9.2	1	5	7.25	—
50-100	75.9	57.3	14	7	10.9	11.3	+04	+3.7	24	10	15.00	107
100-150	124.8	88.7	23	15	18.8	18.8	0.0	0.0	42	15	22.75	52
150-200	172.5	118.9	33	21	26.8	26.2	-0.6	-2.2	26	20	30.50	34
200-250	224.5	151.7	47	29	35.5	34.3	-1.2	-3.4	47	25	38.25	25
250-300	271.4	182.0	48	34	42.1	41.6	-0.5	-1.2	42	30	46.00	20
300-350	326.4	220.3	64	40	49.8	50.1	+0.3	+0.6	32	35	53.75	17
350-400	370.2	249.2	69	50	57.7	56.9	-0.8	-1.4	30	40	61.50	14
400-450	421.2	286.4	69	57	64.1	64.8	+0.7	+1.1	17	45	69.25	13
450-500	473.4	321.5	80	65	72.3	72.9	+0.6	+0.8	23	50	77.00	11
500-544	525.1	361.5	89	67	78.8	80.9	+2.1	+2.7	23	55	84.75	10

Table 126 summarizes our findings regarding the length of the arm. The relation between our calculated and observed values is again a very close one. The average absolute deviations of the calculated from the observed means of this dimension for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, are all less than 0.75 mm. The corresponding relative deviations are all less than 2.2 per cent.

FIGURE 54

THE GROWTH OF THE LENGTH OF THE ARM IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Length of the arm (mm).

TABLE 127

AVERAGE LENGTH OF THE ARM AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE LENGTH OF ARM (cm)
Liharžik (males)	50.0	9.0
Liharžik (females)	49.0	8.8
Meeh (males)	55.0	9.5
Meeh (females)	50.0	8.0
Quetelet (males)	50.0	8.8
Quetelet (females)	49.4	8.7
Schadow	46.8	10.4
Zeising	....	6.6
Present series (calculated)	50.2	7.7

The growth of the arm has been previously studied by Lafaille, Friedenthal, Fridolin, Burtscher, and Retzius. Our findings are in very close agreement with those reported by these authors, although they are slightly lower than most of their values, and there is great irregularity in the averages of Friedenthal and of Lafaille. These points are brought out in table 178 and figure 54.

There are several sets of observations upon the length of the arm in the newborn. These show great variability, probably because of differences in end-points used in determining this dimension. The chief published averages, together with our calculated natal value, are shown in table 127.

57. Length of Forearm

(Figure 55, Field Graph 58, Tables 128, 129, and 178)

The length of the forearm was measured in a straight line from the middle of the cubital fossa to a line drawn at the base of the thenar and hypothenar eminences. We have no data regarding injection fixation upon this dimension, but both the character of our findings and the results obtained from measuring the superior extremity as a whole indicate that these artifacts are negligible.

TABLE 128

LENGTH OF FOREARM
.13CH(MM.)-1.5MM. (305 CASES)

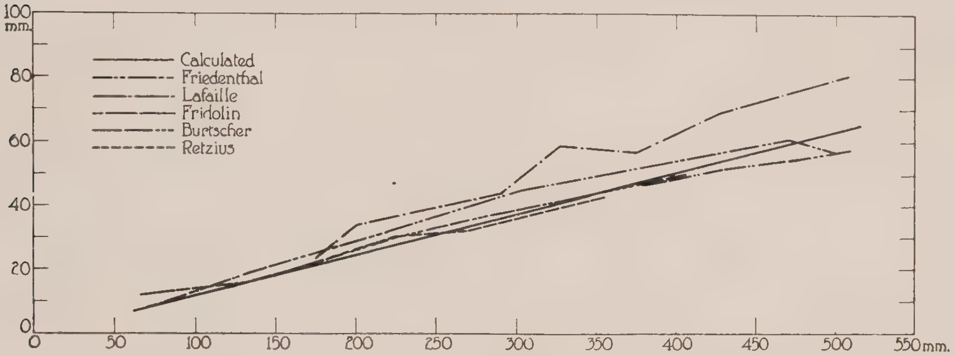
Crown Heel Length (mm.)		Crown Rump Length (mm.)	Length of Forearm (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min.	Mean (a)	Mean (b)	mm.	Per cent.		CH Length (cm.)	Value (mm)	Per cent. increment
23-50	41.0	34.0	4.3	4.3	4.3	3.8	-0.5	-11.6	1	5	5.0	—
50-100	75.9	57.1	11	4	8.2	8.4	+0.2	+2.4	22	10	11.5	130
100-150	124.8	88.7	19	11	15.0	14.7	-0.3	-2.0	42	15	18.0	57
150-200	172.5	118.9	26	16	21.6	20.9	-0.7	-3.2	26	20	24.5	36
200-250	224.5	151.7	34	22	28.8	27.7	-1.1	-3.8	47	25	31.0	27
250-300	271.4	182.0	45	26	34.0	33.8	-0.2	-0.6	42	30	37.5	21
300-350	326.4	220.3	49	33	40.3	40.9	+0.6	+1.5	32	35	44.0	17
350-400	370.2	249.3	57	41	46.5	46.6	+0.1	+0.2	30	40	50.5	15
400-450	421.2	286.4	60	43	52.7	53.2	+0.5	+0.9	17	45	57.0	13
450-500	473.4	321.5	65	53	59.4	60.0	+0.6	+1.0	23	50	63.5	11
500-544	525.1	361.5	76	58	64.7	66.8	+2.1	+3.2	23	55	70.0	10

The results obtained from the study of the growth of the forearm are summarized in table 128. The correspondence between the calculated and observed values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, is again very close. The average absolute deviations are all less than 0.7 mm and the corresponding relative deviations are of the order of 2 per cent.

The growth of this dimension in the fetal period has been previously studied by Lafaille, Fridolin, Friedenthal, Burtscher, Retzius, Reicher, Schultz, and others. The results are shown in tabular form in table 178, and graphically in figure 55. Our findings are in fair agreement with those of Retzius, Fridolin, and Bürtscher, but our values are somewhat lower than those of Friedenthal and of Lafaille.

FIGURE 55

The Growth of the Length of the Forearm in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Length of forearm (mm).

The published values for the length of the forearm in the newborn show great individual variation that is probably dependent upon the technique of measurement. The chief natal averages are summarized in table 129.

TABLE 129

Average Length of Forearm at Birth

Observer	Average body-length (cm)	Average length of forearm (cm)
Liharžik (males)	50.0	7.0
Liharžik (females)	49.0	6.86
Meeh (males)	55.0	7.0
Meeh (females)	50.0	5.5
Quetelet (males)	50.0	5.7
Quetelet (females)	49.6	5.7
Reicher	....	6.85
Schadow	46.8	7.8
Zeising	....	7.5
Present series (calculated)	50.2	6.74

58. Length of Hand

(Figure 56, Field Graph 59, Tables 130, 131, and 178)

This measurement was taken from a line connecting the proximal limits of the thenar and hypothenar eminences to the tip of the middle finger in extension. We have no correction data for the effects of injection and fixation upon this dimension, and, in the light of the statements made in connection with the other segments of the other series of the upper extremity, such a correction seems unnecessary.

TABLE 130

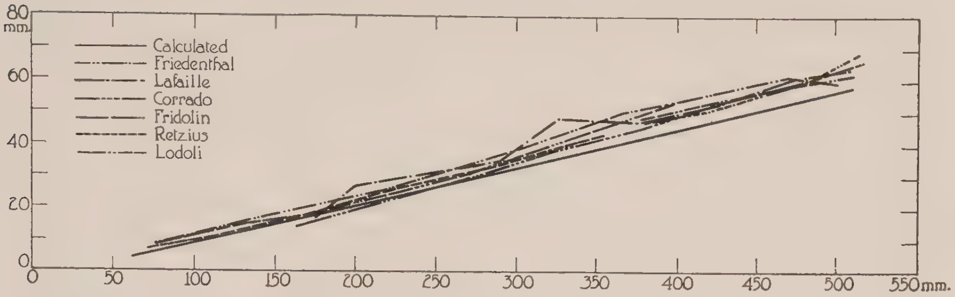
LENGTH OF HAND
.12 CH (MM.) - 3.0 MM. (304 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm.)	Length of Hand (mm.)				Difference between (a) and (b).		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max	Min	Mean (a)		mm	Percent.		CH Length (cm)	Value (mm.)	Per cent increment
23-50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	75.9	57.1	9	4	6.7	6.1	-0.6	-9.0	22	10	9.0	—
100-150	124.8	88.5	14	9	11.6	12.0	+0.4	+3.4	42	15	15.0	67
150-200	172.5	118.9	21	13	16.5	17.7	+1.2	+7.3	26	20	21.0	40
200-250	224.5	151.7	29	18	23.8	23.9	+0.1	+0.4	47	25	27.0	29
250-300	271.4	182.0	33	25	29.4	29.5	+0.1	+0.3	42	30	33.0	22
300-350	326.4	220.3	44	29	37.1	36.2	-0.9	-2.4	32	35	39.0	18
350-400	370.2	249.6	48	35	41.3	41.4	-0.1	-0.2	30	40	45.0	15
400-450	421.2	286.4	53	45	48.3	47.5	-0.8	-1.7	17	45	51.0	13
450-500	473.4	321.5	62	50	54.7	53.8	-0.9	-1.6	23	50	57.0	12
500-544	521.1	361.5	65	54	59.2	60.0	+0.8	+1.4	23	55	63.0	11

Table 130 summarizes our observations on the length of the hand. Our calculated values for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, show average absolute deviations of the order of 0.5 to 0.6 mm, and average relative deviations of the order of 2 to 3 per cent, from the corresponding observed means. The growth of the length of the hand in the fetal period has been previously studied by Burtscher, Friedenthal, Lafaille, Corrado, Fridolin, Retzius, and Lodoli. Their findings are given in table 178 and are represented in figure 56. Our calculated values are somewhat below those of most observers, probably because we used the base of the hand rather than the skeletal elevations of the wrist as the proximal landmarks in making this measurement.

FIGURE 56

THE GROWTH OF THE LENGTH OF THE HAND IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Length of the hand (mm).

There are a number of observations on the length of the hand in the newborn. The chief of these, together with our calculated natal value as computed with use of the empirical formula with graphically determined constants, are given in table 131.

TABLE 131

AVERAGE LENGTH OF THE HAND AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE LENGTH OF HAND (cm)
Daffner (males)	....	6.36
Daffner (females)	....	6.06
Liharžik (males)	50.0	6.00
Liharžik (females)	49.0	5.88
Meeh (males)	55.0	6.5
Meeh (females)	50.0	6.5
Quetelet (males)	50.0	6.1
Quetelet (females)	49.6	6.0
Reicher	....	6.05
Schadow	46.8	5.2
Taylor (males)	51.2	7.2
Taylor (females)	50.0	7.0
Zeising	....	6.0
Present series (calculated)	50.2	5.7

59. Length of Middle Finger

(Field Graph 60, Tables 132 and 178)

This measurement was made from the proximal to the distal end of the extended middle finger. We have no correction data for the injection and preservation artifacts of this dimension.

TABLE 132

LENGTH OF MIDDLE FINGER
.075 CH (MM.)-3.0 MM. (292 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Length of Middle Finger (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		CH Length (cm)	Value (mm)	Per cent. increment
23-50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	81.3	65.7	5	3	4.1	3.1	-1.0	-24.4	12	10	4.50	—
100-150	124.4	88.5	10	5	7.0	6.3	-0.7	-10.0	41	15	8.25	—
150-200	172.5	118.9	12	7	9.4	9.9	+0.5	+5.3	26	20	12.00	84
200-250	224.5	151.7	18	11	13.8	13.8	±0.0	±0.0	47	25	15.75	45
250-300	271.4	182.0	20	14	16.8	17.4	+0.6	+3.6	42	30	19.50	31
300-350	326.4	220.3	28	16	21.5	21.5	±0.0	±0.0	32	35	23.25	24
350-400	370.9	249.6	29	21	24.2	24.8	+0.6	+2.5	29	40	27.00	16
400-450	421.2	286.4	33	24	28.7	28.6	-0.1	-0.3	17	45	30.75	14
450-500	473.4	321.5	38	28	32.5	32.5	±0.0	±0.0	23	50	34.50	12
500-544	525.1	361.5	44	32	36.5	36.4	-0.1	-0.3	23	55	38.25	11

Table 132 summarizes our findings regarding the growth in length of the middle finger. The absolute deviations of the calculated values from the observed means for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, are of the order of 0.4 mm in most instances. The corresponding relative deviations range from about 3.5 to over 4.5 per cent.

The only published observations on the growth of this dimension in the fetal period seemed to be those of Lafaille. While his 5 cm interval averages give rather irregular values, the general course of growth as determined from his data is quite similar to that indicated by our calculated curve. We have found no published observations on the length of the middle finger in the newborn. The calculated natal value (at 50.2 cm crown-heel length) is 3.47 cm when computed by the empirical formula with constants graphically determined.

60. Circumference of Arm

(Field Graph 61, Table 133)

This circumference was taken at the level of the greatest thickness of the arm below the insertion of the deltoid muscle. The measurement was made with a linen thread by the method described in the section on technique. The circumference of the arm is increased 7.2 per cent by injection, and subsequent immersion in formalin raises this to 10.5 per cent at three months. Later there is a slow decrease, the correction figure at six months being −8.2 per cent.

TABLE 133

CIRCUMFERENCE OF ARM
.195CH (MM.) - 8.0MM. (294 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			(b) Calculated						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		C H Length (cm.)	Value (mm)	Per cent. increment
23- 50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	85.8	63.5	13	8	10.3	8.7	- 1.6	-15.5	13	10	11.50	—
100-150	124.4	88.5	23	11	16.7	16.3	- 0.4	- 2.4	41	15	21.25	85
150-200	172.5	118.9	31	19	25.7	25.6	- 0.1	- 0.4	26	20	31.00	46
200-250	224.5	151.7	47	21	36.1	35.8	- 0.3	- 0.8	47	25	40.75	31
250-300	271.4	182.0	55	34	43.9	44.9	+ 1.0	+ 2.3	42	30	50.50	24
300-350	326.1	220.0	67	47	56.4	55.6	- 0.8	- 14	31	35	60.25	19
350-400	370.2	249.2	87	51	62.7	64.2	+ 1.5	+ 2.4	30	40	70.00	16
400-450	421.2	280.4	88	60	76.2	74.1	- 2.1	- 2.8	17	45	79.75	14
450-500	473.4	321.5	102	71	88.9	84.3	-4.6	- 5.2	23	50	89.50	12
500-544	525.1	361.5	126	83	105.0	94.4	-10.6	-10 1	23	55	99.25	11

Our findings in respect to this dimension are summarized in table 133. The calculated values, as determined by our empirical formulae, show mean absolute deviations of 1.8 to 2.3 mm, and relative deviations of 2.8 to 3.7 per cent, from the corresponding observed averages for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive. The largest deviations are in the 5 to 10 cm interval of crown-heel length and in the intervals above 45 cm. The deviations in the 5 to 10 cm interval probably represent a true lack of fit of this part of the curve, due to the fact that this part of the body has not yet assumed the rectilinear type of growth with respect to the crown-heel length, which is characteristic of the fetal period. The discrepancies in the upper two 5 cm intervals seem to be caused by injection.

We found no published observations on this dimension in the fetus. Quetelet obtained a value of 9.1 cm for the living, newborn males (at 50.0 cm crown-heel length) and 9.0 cm for living, newborn females (at 49.4 cm crown-heel length). Our calculated natal value (at 50.2 cm crown-heel length) is 8.9 cm.

61. Circumference of Forearm

(Field Graph 62, Table 134)

This dimension represents the maximum circumference of the forearm. We have no correction data for the effect of formalin artifacts upon it, but our observed averages, as well as the characteristic changes in the circumference of the arm, indicate that it is little affected by artifacts except in our largest specimens.

TABLE 134

CIRCUMFERENCE OF FOREARM
.195 CH (MM.) - 7.5 MM (290 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			(b) Calculated						
Range	Mean		Max	Min.	Mean (a)		mm.	Per cent.		C.H. Length (cm)	Value (mm)	Per cent. increment
23-50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	87.4	64.2	12	8	10.7	9.5	-1.2	-11.2	10	10	12.00	—
100-150	124.4	88.5	25	12	16.7	16.8	+0.1	+0.6	41	15	21.75	81
150-200	172.5	118.9	32	20	26.0	26.1	+0.1	+0.4	26	20	31.50	45
200-250	224.5	151.7	45	22	36.4	36.3	-0.1	-0.3	47	25	41.25	31
250-300	271.4	182.0	58	37	44.8	45.4	+0.6	+1.3	42	30	51.00	24
300-350	326.1	220.0	71	48	57.0	56.1	-0.9	-1.6	31	35	60.75	19
350-400	370.2	249.2	82	53	63.0	64.7	-1.7	-2.7	30	40	70.50	16
400-450	421.2	286.4	92	60	77.5	74.6	-0.9	-1.2	17	45	80.25	14
450-500	473.4	321.5	104	74	89.3	84.8	-4.5	-5.0	23	50	90.00	12
500-544	525.1	361.5	124	85	104.7	94.9	-9.8	-9.4	23	55	99.75	11

Table 134 summarizes our findings and computations for this dimension. Considering that this is the circumference of a soft part, the deviations of our calculated from the observed values are not great. The average absolute deviations of the calculated from the observed means of forearm circumference for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, range from about 1.7 to about 2.0 mm. The corresponding relative deviations range from about 2 to about 3.6 per cent. The largest deviations are in the 45 to 55 cm intervals. They are negative and are probably due to formalin artifacts.

We have found no published observations upon this dimension in the fetus. Quetelet found the forearm circumference to be 7.5 cm in newborn males (at 50.0 cm crown-heel length) and 7.4 cm in the newborn females (at 49.6 cm crown-heel length). Our calculated natal value, computed from the empirical formula with constants graphically determined (at 50.2 crown-heel length), is 9.0 cm.

62. Circumference of Wrist

(Field Graph 63, Table 135)

This dimension represents the perimeter of the distal end of the forearm. We have no data on the effects of formalin artifacts on this circumference, but it is probable that they are relatively small.

TABLE 135

Circumference of Wrist
.165 CH (mm.) - 10.0 mm. (275 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Circumference of Wrist (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				CH Length (cm.)	Value (mm.)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)		mm.	Percent.				
23-50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	81.0	61.0	5	5	5.0	4.5	- 0.5	-10.0	1	10	6.50	—
100-150	127.3	90.3	18	10	12.4	11.9	- 0.5	- 4.0	35	15	14.75	127
150-200	172.0	118.4	22	14	18.2	19.0	+0.8	+4.4	25	20	23.00	56
200-250	224.5	151.7	32	16	26.3	27.4	+1.1	+4.2	47	25	31.25	36
250-300	271.4	182.0	40	26	33.0	34.9	+ 1.9	+ 5.7	42	30	39.50	26
300-350	326.4	220.3	54	37	43.5	43.7	+0.2	+ 0.5	32	35	47.75	21
350-400	370.2	249.2	64	35	48.5	50.7	+2.2	+4.5	30	40	56.00	17
400-450	421.2	286.4	72	45	58.5	58.9	+0.4	+ 0.7	17	45	64.25	15
450-500	473.4	321.5	78	60	68.3	67.2	- 1.1	- 1.6	23	50	72.50	13
500-544	525.1	361.5	87	64	78.2	75.5	- 2.7	- 3.5	23	55	80.75	11

Table 135 gives the summary of our findings for this dimension. Our calculated values show an average absolute deviation from the corresponding observed means for the 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, ranging from 1.1 to 2.2 mm. Most of the corresponding percentage deviations are of the order of 5.0 per cent although they range from 3.6 to 5.7 per cent.

We have found no published observations on the circumference of the wrist in the fetal period or at birth. The calculated natal value, computed with the empirical formulae having graphically determined constants (at 50.2 cm crown-heel length), is 7.3 cm.

III. Résumé and Discussion of Findings on the External Dimensions of the Upper Extremity

The empirical formulae for the external linear dimensions of the upper extremity (as determined by graphic methods) all show negative secondary or *b* constants. These constants tend to increase in absolute size proximo-distally, that for the forearm being larger than that for the arm, and those for the length of the hand and the length of the finger being larger than that for the forearm. Similarly the secondary or *b* constant for the forearm circumference is larger in absolute value than that for the arm circumference, and the constant for the wrist circumference is larger than that for the forearm circumference.

TABLE 136

Calculated Values of the External Dimensions of the Upper Extremity at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Formulae		Calculated values (mm.) at crown-heel lengths of:									
	a	b	5cm.	10cm.	15cm.	20cm.	25cm.	30cm.	35cm.	40cm.	45cm.	50cm.
Length of upper extremity	.4	−4.0	16.0	36.0	56.0	76.0	96.0	116.0	136.0	156.6	176.0	196.0
Arm length (acromion to elbow)	.155	−0.5	7.3	15.0	22.8	30.5	38.3	46.0	53.8	61.5	69.3	77.0
Forearm length	.13	−1.5	5.0	11.5	18.0	24.5	31.0	37.5	44.0	50.5	57.0	63.5
Hand length	.12	−3.0	3.0	9.0	15.0	21.0	27.0	33.0	39.0	45.0	51.0	57.0
Middle finger length	.075	−3.0	0.8	4.5	8.3	12.0	15.8	19.5	23.3	27.0	30.8	34.5
Arm circumference	.192	−7.0	2.6	12.2	21.8	31.4	41.0	50.6	60.2	69.8	79.4	89.0
Forearm circumference	.195	−7.5	2.3	12.0	21.8	31.5	41.3	51.0	60.8	70.5	80.3	90.0
Wrist circumference	.165	−10.0	—	6.5	14.8	23.0	31.3	39.5	47.8	56.0	64.3	72.5

The calculated values for these dimensions at each 5 cm interval of crown-heel length from 5 to 55 cm, inclusive, are given in the tables for individual measurements (tables 124, 126, 128, 130, 132, 133, 134, and 135). These tables include the absolute and percentage increments for each 5 cm interval of crown-heel length.

Table 136 also summarizes the calculated values for these dimensions with respect to crown-heel body-length (from 5 to 50 cm, inclusive), and table 137 gives the computed values at the close of each month of the fetal period from three to ten months, inclusive. Figures 57 and 58 are graphic representations of the values shown in tables 136 and 137, respectively.

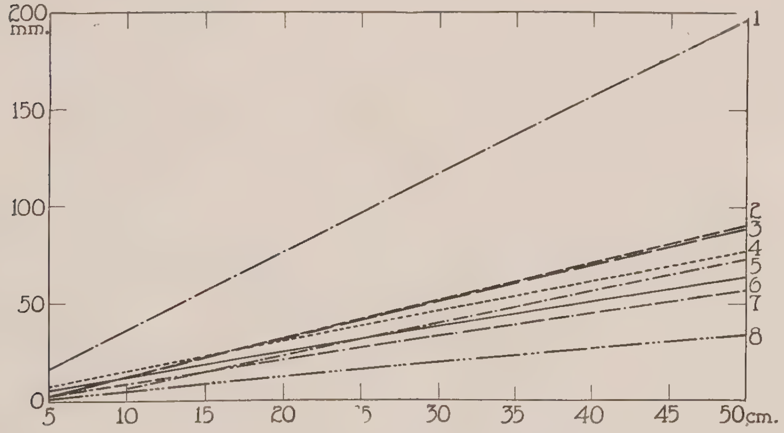
TABLE 137

Calculated Values of the External Dimensions of the Upper Extremity at the Close of Each Month of the Fetal Period

Dimension	Formulae		Calculated values (mm.) at:							
	a	b	3mo.	4mo.	5mo.	6mo.	7mo.	8mo.	9mo.	10mo.
Length of upper extremity	.4	- 4.0	24.3	58.2	87.2	112.8	136.2	157.7	177.9	196.8
Arm length (acromion to elbow)	.155	- 0.5	10.5	23.6	34.8	44.8	53.8	62.2	70.0	77.3
Forearm length	.13	- 1.5	7.7	18.7	28.1	36.5	44.1	51.1	57.6	63.8
Hand length	.12	- 3.0	5.5	15.6	24.3	32.0	39.1	45.5	51.6	57.2
Middle finger length	.075	-3.0	2.3	8.7	14.1	18.9	23.3	27.3	31.1	34.7
Arm circumference	.192	- 7.0	6.6	22.8	36.8	49.1	60.3	70.6	80.3	89.4
Forearm circumference	.195	- 7.5	6.3	22.8	36.9	49.4	60.8	71.3	81.2	90.4
Wrist circumference	.165	-10.0	1.7	15.6	27.6	38.2	47.8	56.7	65.0	72.8

FIGURE 57

The Growth of the External Dimensions of the Upper Extremity (as Determined by Empirical Formulae) in the Fetal Period with Respect to the Growth in Crown-Heel Length



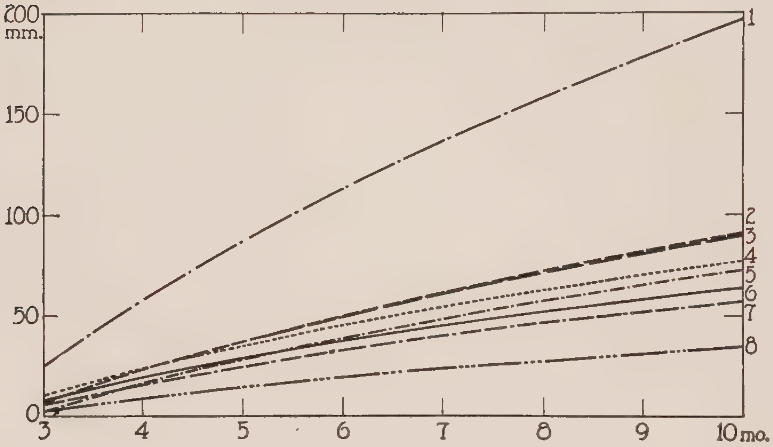
Abscissa: Crown-heel length (cm). Ordinates: Dimensions of the upper extremity.

1. Length of upper extremity	5. Circumference of wrist
2. Circumference of forearm	6. Length of forearm
3. Circumference of arm	7. Length of hand
4. Length of arm	8. Length of middle finger

The computed absolute and percentage increments of each of these dimensions in each month are included in tables 138 and 139. In the fourth month the absolute increments range from 6.3 mm for the length of the little finger, to 33.8 mm for the length of the upper extremity as a whole. These increments decline rather slowly, the range in the seventh month being from 4.4 mm for the length of the middle finger, to 23.4 mm for the length of the upper extremity as a whole. In the last month of prenatal life the absolute increments range from 3.5 mm to 18.9 mm for the above dimensions.

FIGURE 58

The Growth of the External Dimensions of the Upper Extremity (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: External dimensions of the upper extremity (mm).

1. Length of upper extremity
2. Circumference of forearm
3. Circumference of arm
4. Length of arm
5. Circumference of wrist
6. Length of forearm
7. Length of hand
8. Length of middle finger

The percentage increments in the fourth month are relatively enormous, their range for the linear dimensions being from 124.8 per cent for the arm length, to 273.9 per cent for the length of the middle finger. The range of the percentage increments of the circumferences is from 245.5 per cent for the arm to 823.5 per cent for the wrist. By the seventh month these increments have undergone a marked decline, the range for the entire group of dimensions being from 20.3 for the arm length to 25.4 for the wrist circumference. In the tenth month the increments are approximately half those of the seventh, the range being from 10.4 for the arm length to 12.0 for the wrist circumference.

TABLE 138

Calculated Absolute Increments of the External Dimensions of the Upper Extremity in Each Month of the Fetal Period

Dimension	Absolute increments (mm.) in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Length of upper extremity	33.8	29.0	25.6	23.4	21.5	20.2	18.9
Arm length (acromion to elbow)	13.1	11.2	9.9	9.1	8.3	7.8	7.3
Forearm length	11.0	9.4	8.3	7.6	7.0	6.6	6.1
Hand length	10.1	8.7	7.7	7.0	6.5	6.0	5.7
Middle finger length	6.3	5.4	4.8	4.4	4.0	3.8	3.5
Arm circumference	16.2	13.9	12.3	11.2	10.3	9.7	9.1
Forearm circumference	16.5	14.1	12.5	11.4	10.5	9.8	9.2
Wrist circumference	14.0	12.0	10.6	9.7	8.9	8.3	7.8

The per cent of the natal value attained by each dimension at each 5 cm interval of crown-heel length is shown in table 140. At a crown-heel length of 10 cm the computed arm length is 19.5 per cent of its newborn size, while the computed wrist circumference is but 9 per cent of its natal value. At 25 cm crown-heel length the values range from 49.7 per cent for the length of the arm to 43.2 per cent for the wrist circumference. At 45 cm the percentage of natal values attained by the various dimensions range from 88.7 to 90.0.

TABLE 139

Calculated Percentage Increments of the External Dimensions of the Upper Extremity in Each Month of the Fetal Period

Dimension	Percentage increments in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Length of upper extremity	139.1	49.8	29.4	20.7	15.8	12.8	10.6
Arm length (acromion to elbow)	124.8	47.5	28.4	20.3	15.4	12.5	10.4
Forearm length	142.9	50.3	29.5	20.8	15.9	12.9	10.6
Hand length	183.6	55.8	31.7	22.2	16.6	13.4	11.0
Middle finger length	273.9	62.1	32.7	21.9	17.2	13.9	11.3
Arm circumference	245.5	61.0	33.4	22.8	17.1	13.7	11.3
Forearm circumference	261.9	61.8	33.9	23.1	17.3	13.7	11.3
Wrist circumference	823.5	76.9	38.4	25.4	18.6	14.6	12.0

The calculated percentages of natal values attained by the various dimensions at the close of each month of the fetal period are shown in table 141. At three months the length of the entire upper extremity is 12.3 per cent of the birth value, and the corresponding values for its various segments range from 9.6 per cent for the middle finger length to 13.6 per cent for the forearm length. At six months all external dimensions of the upper extremity have attained over half of their total prenatal growth, the values ranging from 54.5 per cent for the arm circumference to 58.0 per cent for the forearm length. At nine months all of the external dimensions are approximately

TABLE 140

Per Cent of Natal Value Attained by Each External Dimension of the Upper Extremity at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Percentage of natal value at crown-heel lengths of:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Length of upper extremity	8.2	18.4	28.6	38.8	49.0	59.2	69.4	79.6	89.8	100.0
Arm length (acromion to elbow)	9.5	19.5	29.6	39.6	49.7	59.7	69.9	79.9	90.0	100.0
Forearm length	7.9	18.1	28.3	38.6	48.8	59.1	69.3	79.5	89.8	100.0
Hand length	5.3	15.8	26.3	36.8	47.4	57.9	68.4	78.9	89.5	100.0
Middle finger length	2.3	13.0	24.1	34.8	45.8	56.5	67.5	78.3	89.2	100.0
Arm circumference	2.9	13.7	24.5	35.3	46.1	56.9	67.6	78.4	89.2	100.0
Forearm circumference	2.6	13.3	24.2	35.0	45.9	56.7	67.6	78.3	89.2	100.0
Wrist circumference	—	9.0	20.4	31.7	43.2	54.5	65.9	77.2	88.7	100.0

TABLE 141

Per Cent of Natal Value Attained by Each External Dimension of the Upper Extremity at the Close of Each Month of the Fetal Period

Dimension	Percentage of natal value at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Length of upper extremity	12.3	29.6	44.3	57.3	69.2	80.1	90.4	100.0
Arm length (acromion to elbow)	11.2	28.6	43.5	56.8	68.8	79.8	90.2	100.0
Forearm length	13.6	30.5	45.0	58.0	69.6	80.5	90.6	100.0
Hand length	12.1	29.3	44.0	57.2	69.1	80.0	90.2	100.0
Middle finger length	9.6	27.3	42.5	55.9	68.4	79.5	90.2	100.0
Arm circumference	6.6	25.1	40.6	54.5	67.1	78.7	89.6	100.0
Forearm circumference	7.4	25.5	41.2	54.9	67.4	79.0	89.8	100.0
Wrist circumference	7.0	25.2	40.8	54.6	67.3	78.9	89.8	100.0

nine-tenths of their natal size, the calculated percentage values ranging from 89.8 for the forearm and wrist circumferences to 90.6 for the forearm length.

TABLE 142

Relative Size of the External Dimensions of the Upper Extremity (Computed as Per Cents of the Crown-Heel Length) at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Per cent. of total (crown-heel) length at:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Length of upper extremity	32.0	36.0	37.3	38.0	38.4	38.7	38.9	39.0	39.1	39.2
Arm length (acromion to elbow)	14.6	15.0	15.2	15.3	15.3	15.3	15.4	15.4	15.4	15.4
Forearm length	10.0	11.5	12.0	12.3	12.4	12.5	12.6	12.6	12.7	12.7
Hand length	6.0	9.0	10.0	10.5	10.8	11.0	11.1	11.3	11.3	11.4
Middle finger length	1.6	4.5	5.5	6.0	6.3	6.5	6.7	6.8	6.8	6.9
Arm circumference	5.2	12.2	14.5	15.7	16.4	16.9	17.2	17.5	17.6	17.8
Forearm circumference	4.6	12.0	14.5	15.8	16.5	17.0	17.4	17.6	17.8	18.0
Wrist circumference		6.5	9.9	11.5	12.5	13.2	13.7	14.0	14.3	14.5

Table 142 shows the calculated relative size of the various external dimensions of the upper extremity at successive 5 cm intervals of crown-heel length. All of these dimensions show an increase in relative length during the fetal period. The length of the upper extremity is equivalent to 32 per cent of the body-length at 5 cm crown-heel length, 38.4 per cent at 25 cm, and 39.2 per cent at 50 cm. The arm and forearm lengths show small relative increments, from 14.6 and

TABLE 143

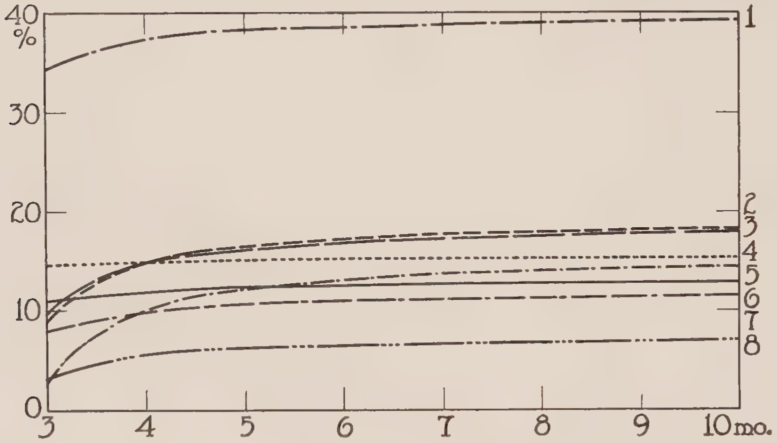
Relative Size of the External Dimensions of the Upper Extremity (Computed as Per Cents of the Crown-Heel Length) at the Close of Each Month of the Fetal Period

Dimension	Per cent. of total (crown-heel) length at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Length of upper extremity	34.3	37.5	38.3	38.6	38.9	39.0	39.1	39.2
Arm length (acromion to elbow)	14.8	15.2	15.3	15.3	15.3	15.4	15.4	15.4
Forearm length	10.9	12.0	12.3	12.5	12.6	12.6	12.7	12.7
Hand length	7.8	10.0	10.7	11.0	11.2	11.3	11.3	11.4
Middle finger length	3.2	5.6	6.2	6.5	6.6	6.8	6.8	6.9
Arm circumference	9.3	14.7	16.1	16.8	17.2	17.5	17.7	17.8
Forearm circumference	8.9	14.7	16.2	16.9	17.3	17.6	17.9	18.0
Wrist circumference	2.4	10.0	12.1	13.1	13.6	14.0	14.3	14.5

10.0 per cent, respectively, at 5 cm crown-heel length, to 15.4 and 12.7 per cent at 50 cm. The greatest relative increment in proportional size is in the length of the middle finger, which rises from 1.6 per cent at 5 cm to 6.9 per cent at 50 cm. The increase in the relative sizes of the arm circumference and forearm circumference, between 10 and 50 cm crown-heel length, is approximately 50 per cent, being somewhat greater for the latter than for the former. The wrist circumference increases from 6.5 to 14.5, in relative size between 10 and 50 cm crown-heel length, a change of over 100 per cent.

FIGURE 59

The Changes in the Relative Size of the External Dimensions of the Upper Extremity in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the dimensions of the upper extremity expressed as per cents of the crown-heel length.

1. Length of upper extremity
2. Circumference of forearm
3. Circumference of arm
4. Length of arm
5. Circumference of wrist
6. Length of forearm
7. Length of hand
8. Length of middle finger

The computed length of the upper extremity as a whole (table 143) is equal to 34.3 per cent of the total body-length at three months, 38.6 per cent at six months, and 39.2 per cent at ten months or birth. The relative length of the arm shows little increase, the calculated values being 14.8 per cent at three months and 15.4 per cent at birth. The greatest increase in any linear dimension of this group is found in the middle-finger length, which is equivalent to 3.2 per cent of the crown-heel length at three months and to 6.9 per cent at ten months. The arm girth is equivalent to 9.3 per cent of the total body-length at three fetal months and to 17.8 per cent at birth. The figures for the forearm are quite similar, although the increase in relative size is a little greater. The relative size of the wrist circumference increases from 2.4 per cent at three months to 13.1 at six months and 14.5 per cent at birth.

The relation of the computed length of the upper extremity to the computed sitting-height or crown-rump length may be illustrated by an index computed by dividing the former dimension by the latter and multiplying the result by 100. Our calculated values for these two dimensions give an index of 42.1 at 5 cm crown-heel length, 56.5 at 25 cm, and 58.5 at 50 cm. This index is 47.0 at three fetal months, 57.1 at six months, and 58.5 at ten months or birth.

Among the more interesting problems in the growth of the extremities is the relation of the length of the forearm to that of the arm in the fetal period. It has been claimed by Hamy and by Corréa that the length of the forearm, relative to that of the arm, decreases during the fetal period. On the other hand Schultz ('23, '26) and Reicher ('25) find that during the third and fourth months the forearm grows much more rapidly than the arm. These relations are often represented by the brachial index, which consists of the length of the forearm multiplied by 100, and divided by the length of the arm. Since this relation has been a matter of dispute we have determined these indices for our *computed* values as obtained by the three methods of curve fitting which we have employed. Using the constants of our formulae as determined by graphic methods we find that the brachial index is 68.5 at 5 cm crown-heel length, 80.9 at 25 cm, and 82.5 at 50 cm. The corresponding values for intervals of time are 73.3 at three fetal months, 81.5 at six months, and 82.5 at ten months or birth. When computed from the empirical formulae, with the constants determined by the method of averages, the brachial index is 73.7 at 5 cm crown-heel length, 81.0 at 25 cm, and 81.9 at 50 cm. The same index for intervals of time is 76.3 at three fetal months, 81.3 at six months, and 82.0 at birth. Using the empirical formulae with the constants determined by the method of least squares, the brachial index is 71.5 at 5 cm crown-heel length, 80.5 at 25 cm, and 81.7 at 50 cm; and 74.8 at three months, 80.9 at six months, and 81.7 at birth. Thus, although our figures show some variation dependent upon the method employed in computing the calculated values, they all show an increase in the brachial index in the fetal period. In other words, our figures support the views of Schultz and of Reicher as opposed to those of Hamy and of Corréa.

The forearm-hand index is obtained by multiplying the hand length by 100 and dividing by the length of the forearm. Computing this index according to our calculated values from formulae by graphic methods we obtain a value of 60.0 at 5 cm crown-heel length, 87.1 at 25 cm, and 89.8 at 50 cm. In relation to time this index is 71.4 at three fetal months, 87.7 at six months, and 89.7 at ten months. Thus our figures indicate a constant increase in the length of the hand with respect to the forearm in the fetal period. Schultz has found a similar increase from the fifth fetal month to birth, but he records a decrease in the third and fourth months. The indices of Reicher are quite irregular but show a trend towards increase in the fetal period.

The relations in the girths of the arm and forearm may be determined by the arm-proportion index, which is computed by dividing the maximum girth of the forearm by the maximum girth of the arm and dividing the result by 100. According to our figures this index is 88.5 at 5 cm crown-heel length, 100.7 at 25 cm, and 101.1 at 50 cm; or, 95.5 at three fetal months, 100.6 at six months, and 101.1 at ten months or birth. In other words, the girth of the forearm is increasing more rapidly than that of the arm in the fetal period, a fact that is evident from the other forms of computation that we have presented.

PART VIII

SUMMARY OF FINDINGS ON THE EXTERNAL DIMENSIONS OF THE LOWER EXTREMITY

I. Introductory Note

Eight dimensions were measured in connection with the study of the lower extremity. Six were linear measurements: two lengths of the thigh (from the posterior superior spine of the ilium to the knee and from the greater trochanter to the knee); the length of the leg; the height of the foot; the length of the foot; and the length of the lower extremity as a whole as determined by adding the length of the thigh from trochanter to knee, the length of the leg, and the height of the foot. The circumferential growth of the lower extremity was followed by measurements of the girth of the thigh and the maximum girth of the calf. A part of the lower extremity is included in the intertrochanteric diameter, which is discussed in connection with the pelvis.

II. Consideration of Individual Dimensions*

63. Lower Extremity Length

(Figure 60, Field Graph 56, Tables 144, 145, 177, and 180)

The length of the lower extremity as determined in this study represents the distance from the upper lateral surface of the greater trochanter of the femur to the sole of the foot. This value was determined by adding the length of the thigh, the length of the leg, and the height of the foot, for the extremities of our specimens were usually flexed.

The length of the lower extremity is increased 0.8 per cent by formalin injection. The subsequent changes in formalin preservation are very slight but irregular. After injection and six months' preservation, the average value for preserved material is 0.9 per cent greater than in fresh specimens.

Table 144 summarizes our findings and computations for this dimension. The fit between our observed and calculated values is a fairly close one. The average absolute deviations for the 5 cm crown-heel intervals, from 5 to 55 cm, inclusive, range between 1

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* The plan used in preparing the following summaries is described in Part I, Section IV (p. 54) of this monograph.

TABLE 144

LENGTH OF LOWER EXTREMITY
43 CH (MM.) - 7.0 MM. (315 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Length (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		C.H. Length (cm.)	Value (mm.)	Per cent. increment
23-50	35.4	30.3	15	3	8.2	8.2	0.0	0.0	12	5	14.5	—
50-100	75.3	56.9	32	14	23.9	25.4	+ 1.5	+6.3	25	10	36.0	148
100-150	124.8	88.7	57	35	45.7	46.7	+ 1.0	+2.2	39	15	57.5	60
150-200	172.5	118.9	76	56	65.9	67.2	+ 1.3	+2.0	26	20	79.0	37
200-250	224.5	151.6	106	75	90.7	89.5	- 1.2	- 1.3	46	25	100.5	27
250-300	271.4	182.0	129	93	110.3	109.7	- 0.6	- 0.5	42	30	122.0	21
300-350	326.4	220.3	155	118	133.2	133.4	+ 0.2	+0.2	32	35	143.5	18
350-400	370.2	249.2	169	133	150.3	152.2	+ 1.9	+ 1.3	30	40	165.5	15
400-450	421.2	286.4	185	153	170.1	174.1	+4.0	+2.4	17	45	186.5	13
450-500	473.4	321.5	211	174	197.2	196.6	- 0.6	- 0.3	23	50	208.0	12
500-544	525.1	361.5	248	205	221.0	218.8	- 2.2	- 1.0	23	55	229.5	10

TABLE 145

AVERAGE LENGTH OF THE LOWER EXTREMITY AT BIRTH

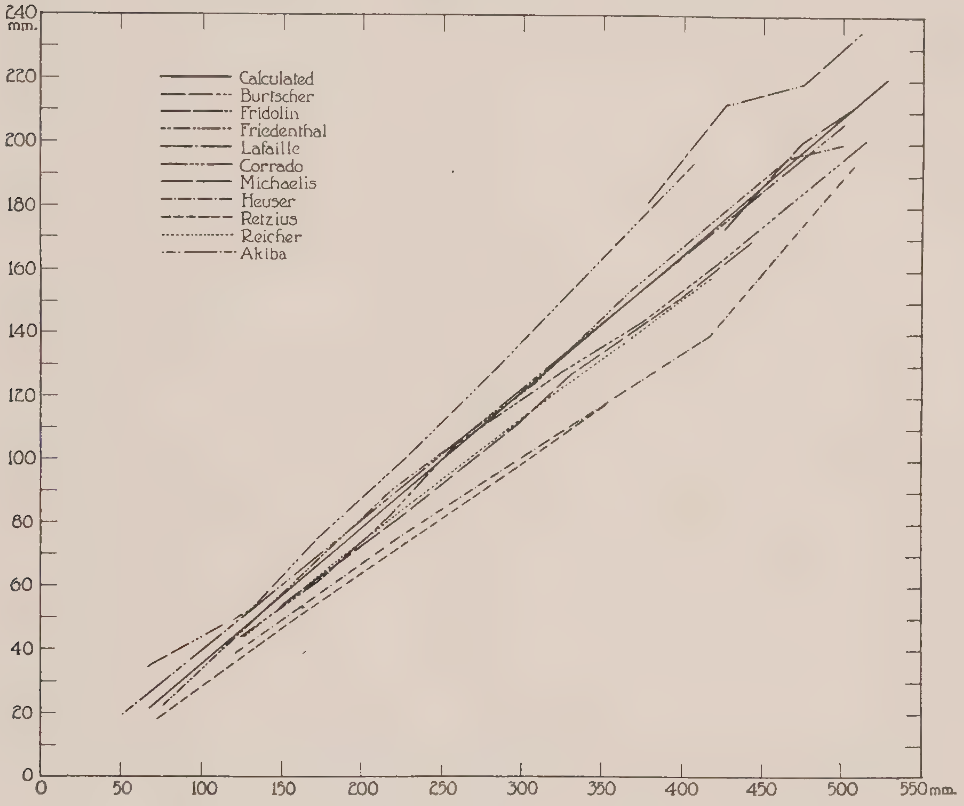
OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE LENGTH OF LOWER EXTREMITY (cm)
Le Damany (males)	49.3	17.66
Le Damany (females)	49.0	17.65
Orchansky (males)	49.52	24.38
Orchansky (females)	48.3	23.9
Quetelet (males)	50.0	19.5
Quetelet (females)	49.6	19.3
Ranke (males)	49.9	16.9
Ranke (females)	48.6	16.6
Reicher (males)	49.5	18.85
Reicher (females)	50.0	18.38
Schultz (estimated from graph)	54.0	19.+
Taylor (males)	51.2	19.0
Taylor (females)	50.0	18.8
Weissenberg (males)	50.8	20.5
Weissenberg (females)	50.0	20.3
Present series (calculated)	50.2	20.9

and 1.5 mm, and the corresponding mean relative deviations are 1.83 per cent or less.

The growth of the lower extremity in the fetal period has been previously studied by Burtscher, Fridolin, Friedenthal, Lafaille, Michaelis, Heuser, Corrado, Retzius, Reicher, Schultz, and others. When the findings of these observers are plotted they show great variation, which may be due, in part, to differences in the proximal end-point used in determining this dimension. The curve of our calculated values falls fairly through the center of this distribution, our results approximating those of Friedenthal (see tables 177 and 180 and figure 60). There are a number of published observations

FIGURE 60

The Growth of the Length of the Lower Extremity in the Fetal Period as Determined by Various Observers



Abscissa: Crown-heel length (mm). Ordinate: Length of lower extremity (mm).

on the length of the lower extremity at birth. The chief of these, together with our calculated natal value, are given in table 145.

64. Length of Thigh (Posterior Superior Spine of Ilium to Knee)

(Field Graph 64, Table 146)

This measurement was taken as a straight line from the posterior superior spine of the ilium to the level of the lower margin of the lateral condyle of the femur. We have no experimental data on the effects of formalin artifacts upon this dimension, but since the change in the length of the inferior extremity as a whole through preservation and injection amounts to less than 1 per cent, it is probable that the effect of these factors on the length of the thigh is negligible.

TABLE 146

LENGTH OF THIGH (POSTERIOR-SUPERIOR SPINE OF ILIUM TO KNEE)
.25CH(MM.) - 2.0MM. (299 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm)	Length of Thigh (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		CH Length (cm)	Value (mm.)	Per cent. increment
23 - 50	41.0	34.0	—	—	8.5	8.3	0.2	2.4	1	5	10.5	—
50-100	77.9	58.5	21	10	16.6	17.5	+0.9	+5.4	18	10	23.0	119
100-150	125.0	88.9	38	21	29.3	29.3	±0.0	±0.0	40	15	35.5	54
150-200	172.5	118.9	47	33	40.9	41.1	+0.2	+0.5	26	20	48.0	35
200-250	224.5	151.7	66	46	55.4	54.1	-1.3	-2.3	47	25	60.5	26
250-300	271.5	182.0	79	56	66.0	65.9	-0.1	-0.2	42	30	73.0	21
300-350	326.4	220.3	92	66	79.2	79.6	+0.4	+0.5	32	35	85.5	17
350-400	370.2	249.2	103	80	89.3	90.6	+1.3	+1.5	30	40	98.0	15
400-450	421.2	286.4	120	89	104.5	103.3	-1.1	-1.1	17	45	110.5	13
450-500	473.4	321.5	131	105	119.2	116.4	-2.8	-2.3	23	50	123.0	11
500-544	525.1	361.5	138	110	129.9	129.8	-0.1	-0.1	23	55	135.5	10

Table 146 summarizes our findings and computations for this measurement of the thigh. The average absolute deviations of the observed from the calculated values for 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, are of the order of 0.8 mm or less. The corresponding relative deviations range from 1.2 to 1.4 per cent.

Most, if not all, observers who have studied the growth of the thigh in fetal life, appear to have measured the distance from the trochanter to the knee rather than the dimension considered here. Zeising gives the natal value of this dimension as 15.2 cm. Our calculated newborn value (as estimated by the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is much lower, being 12.4 cm.

65. Length of Thigh (Trochanter to Knee)

(Figure 61, Field Graph 66, Tables 147 and 179)

This measurement represents the distance in a straight line from the proximo-lateral surface of the greater trochanter to the level of the inferior margin of the lateral condyle of the femur. We have no data upon the effect of formalin injection and preservation upon this dimension, but both the regularity of the observed values in the upper part of the distribution, and the small changes produced on the length of the inferior extremity as shown by these artifacts, make it seem very probable that this effect is negligible.

TABLE 147

Length of Thigh (Trochanter to Knee)
.19 CH (mm.) - 2.0 mm. (301 cases)

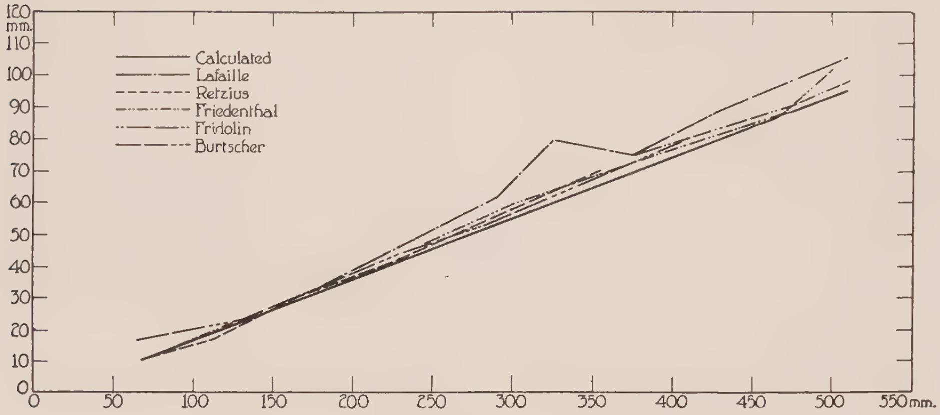
Crown Heel Length (mm.)		Crown Rump Length (mm.)	Length of Thigh (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min.	Mean (a)	Mean (b)	mm.	Per cent.		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	41.0	34.0	—	—	5.9	5.8	-0.1	-1.7	1	5	7.5	—
50-100	78.0	58.6	16	7	12.5	12.8	+0.3	+2.4	20	10	17.0	127
100-150	125.0	88.9	27	17	21.9	21.8	-0.1	-0.5	40	15	26.5	56
150-200	172.5	118.9	35	26	30.8	30.8	±0.0	±0.0	26	20	36.0	36
200-250	224.5	151.7	49	33	41.9	40.7	-1.2	-2.9	47	25	45.5	26
250-300	271.4	182.5	61	41	50.6	49.6	-1.0	-2.0	42	30	55.0	21
300-350	326.4	220.3	74	53	60.6	60.0	-0.6	-1.0	32	35	64.5	17
350-400	370.2	249.2	78	61	68.8	68.3	-0.5	-0.7	30	40	74.0	15
400-450	421.2	286.4	84	67	75.9	78.0	+2.1	+2.1	17	45	83.5	13
450-500	473.4	321.5	99	75	88.3	87.9	-0.4	-0.5	23	50	93.0	11
500-544	525.1	361.5	110	88	97.9	97.8	-0.1	-0.1	23	55	102.5	10

Table 147 summarizes our findings and computations for this measurement of the inferior extremity. The correspondence between the calculated and the observed values for this dimension is quite close. The average absolute deviations of the calculated from the observed means for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, are of the order of 0.6 mm. The corresponding relative deviations range from about 1.3 to 1.5 per cent.

Although most observers of growth of the extremities in prenatal life have not defined their measurements very carefully, it seems that the majority of the published observations on the length of the thigh represent this dimension as defined above. These include the observations by Lafaille, Retzius, Friedenthal, Fridolin, and Burtscher. Our calculated values fall slightly below those of most previous observers, although they are in fairly close agreement with those of Retzius, Friedenthal, and Fridolin.

FIGURE 61

THE GROWTH OF THE LENGTH OF THE THIGH IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Length of thigh (mm).

We have found no published natal value for this dimension except one of 10.35 cm given by Reicher. Our calculated value (computed by the empirical formula with graphically determined constants, at 50.2 cm crown-heel length) is 9.3 cm.

66. Length of Leg

(Figure 62, Field Graph 65, Tables 148, 149, and 179)

This dimension represents the distance in a straight line from the level of the lower margin of the lateral condyle of the femur to the lower margin of the lateral malleolus. We have no correction figure for the effect of formalin injection and preservation upon this dimension, but, from the evidence cited in connection with the other segments of the inferior extremity, it seems probable that this correction would be a negligible one.

Our findings and computations for the length of the leg are summarized in table 148. The average absolute deviations of the calculated values from the corresponding observed means of this dimension for the 5 cm intervals of crown-heel length, from 5 to 55 cm, inclusive, are of the order of 0.5 to 1.0 mm. The corresponding relative deviations range from 1 to about 1.8 per cent.

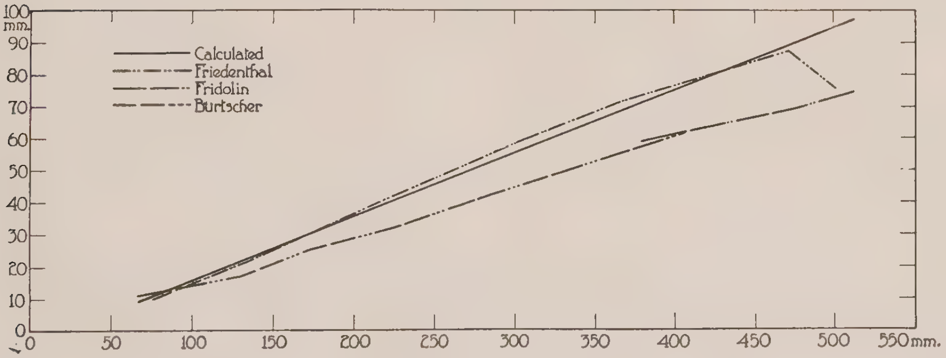
TABLE 148

LENGTH OF LEG (LATERAL EPICONDYLE TO LATERAL MALLEOLUS)
.2 CH (MM.) − 4.5 MM. (299 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Length of Leg (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	41.0	34.0	—	—	4.0	3.7	-0.3	-7.5	1	5	5.5	—
50-100	78.0	58.6	16	7	12.5	12.1	-0.4	-3.2	20	10	15.5	182
100-150	124.9	88.7	26	16	20.9	20.5	-0.4	-1.9	39	15	25.5	65
150-200	172.5	118.9	36	26	30.2	30.0	-0.2	-0.7	26	20	35.5	39
200-250	224.4	151.6	50	35	41.3	40.4	-0.9	-2.2	46	25	45.5	28
250-300	271.4	182.0	59	42	50.0	49.8	-0.2	-0.4	42	30	55.5	22
300-350	326.4	220.3	72	53	60.8	60.8	±0.0	±0.0	53	35	65.5	18
350-400	370.2	249.2	78	60	68.4	69.5	+1.1	+1.6	60	40	75.5	15
400-450	421.2	286.4	84	68	78.3	79.7	+1.4	+1.8	68	45	85.5	13
450-500	473.4	321.5	99	78	90.3	90.2	-0.1	-0.1	78	50	95.5	12
500-544	525.1	361.5	112	91	100.2	100.5	+0.3	+0.3	91	55	105.5	10

FIGURE 62

THE GROWTH OF THE LENGTH OF THE LEG IN THE FETAL PERIOD AS DETERMINED BY VARIOUS OBSERVERS



Abscissa: Crown-heel length (mm). Ordinate: Length of leg (mm).

The growth in the length of the leg in the fetal period has been previously studied by Friedenthal, Fridolin, Burtscher, and others. Our calculated values agree very closely with the findings of Friedenthal but are much higher than the values given by Bürtscher and Fridolin. The available means for this dimension in the newborn are given in table 149.

TABLE 149

Average Length of Leg at Birth

Observer	Average body-length (cm)	Average length of leg (cm)
Liharžik (males)	50.0	9.0
Liharžik (females)	49.0	8.82
Quetelet (males)	50.0	9.1
Quetelet (females)	49.6	8.7
Reicher	....	8.4
Present series (calculated)	50.2	9.6

67. **Height of Foot**

(Figure 63, Field Graph 67, Tables 150 and 179)

This dimension represents the distance in a perpendicular straight line from the lower margin of the lateral malleolus to the sole of the foot. We have no correction data for this measurement.

Our findings and computations for the height of the foot are summarized in table 150. The average weighted deviations of our calculated values from our observed means for this dimension, for the 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, fall between 0.4 and 0.7 mm. The corresponding relative deviations range from about 6 to nearly 9 per cent.

The growth of the height of the foot in the fetal period has been previously studied by Friedenthal and by Lafaille. Our calculated values show the same general course of growth as is indicated by these observers' averages, but are consistently lower over the greater part of the distribution.

Quetelet obtained a natal value for the height of the foot of 2.4 cm for both males and females (at 50.0 and 49.6 cm crown-heel length, respectively). Our calculated natal value (computed at 50.2 cm crown-heel length, with the empirical formula having graphically determined constants) is distinctly lower, being but 1.9 cm.

TABLE 150

Height of Foot (Lateral Malleolus to Sole)
.04 CH (mm.) - 1.5 mm. (298 cases)

Crown Heel Length (mm)		Crown Rump Length (mm.)	Height of Foot (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	41.0	34.0	—	—	0.8	0.14	-0.66	-82.5	1	5	—	—
50-100	78.0	58.6	2.8	1.0	1.8	1.6	-0.2	-11.1	20	10	2.5	—
100-150	124.9	88.7	4.8	2.0	3.1	3.5	+04	+12.9	39	15	4.5	80
150-200	172.5	118.9	7.3	3.2	4.9	54	+0.5	+10.2	26	20	6.5	44
200-250	224.4	151.6	10.0	3.7	7.3	7.5	+0.2	+ 2.7	46	25	8.5	31
250-300	271.4	182.0	13.1	6.0	9.4	94	±0.0	±0.0	42	30	10.5	24
300-350	326.4	220.3	17.0	8.0	11.7	11.6	-0.1	- 0.9	32	35	12.5	19
350-400	369.5	248.5	17.0	10.0	13.1	13.3	+0.2	+ 1.5	29	40	14.5	16
400-450	421.2	286.4	18.5	12.5	15.7	15.3	-04	- 2.5	17	45	16.5	14
450-500	473.4	321.5	24.5	15.0	18.5	17.4	-1.1	- 5.9	23	50	18.5	12
500-544	525.1	361.5	32.0	17.0	22.8	19.5	-3.3	-14.5	23	55	20.5	11

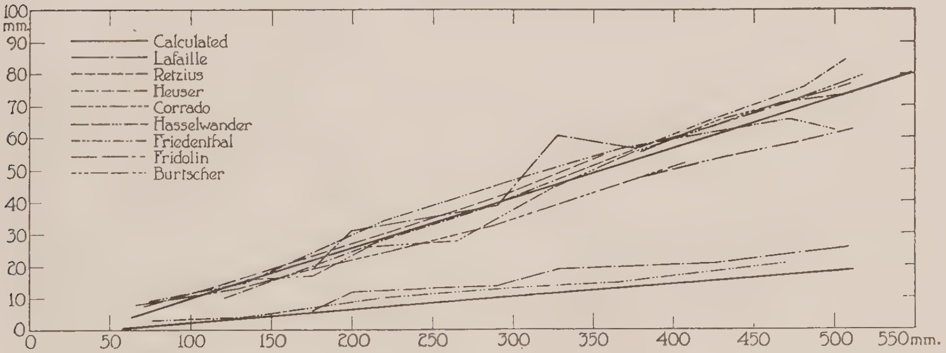
68. Length of Foot

(Figure 63, Field Graph 68, Tables 151, 152, and 179)

This dimension was measured as a straight line from the posterior margin of the heel to the tip of the extended great toe. We have no correction data for the effect of formalin artifacts on this dimension.

FIGURE 63

The Growth of the Foot in the Fetal Period as Determined by Various Observers



The upper group of curves is of foot length and the lower group is of foot height, as determined by various observers. Abscissa: Crown-heel length (mm). Ordinates: Foot length and foot height (mm).

Our findings regarding the length of the foot are summarized in table 151. The average absolute deviations of the calculated values from the corresponding observed means, for the 5 cm intervals of crown-heel length from 10 to 55 cm, inclusive, are of the order 0.6 to 0.7 mm. The corresponding average relative deviations range from 3.2 to 4.0 per cent.

TABLE 151

LENGTH OF FOOT
.16 CH(MM.)-6.5 MM. (299 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Length of Foot (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean(b)						
Range	Mean		Max.	Min.	Mean(a)		mm.	Percent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	77.6	58.4	10	5	8.0	5.9	-2.1	-26.4	21	10	9.5	—
100-150	125.1	88.8	18	10	13.3	13.5	+0.2	+1.5	38	15	17.5	84
150-200	172.0	118.9	24	17	20.1	21.1	+1.0	+5.0	26	20	25.5	46
200-250	224.5	151.7	38	22	29.3	29.4	+0.1	+5.0	47	25	33.5	31
250-300	271.4	182.0	43	31	36.9	36.9	±0.0	±0.0	42	30	41.5	24
300-350	326.4	220.3	56	40	47.1	45.7	-1.4	-3.0	32	35	49.5	19
350-400	370.2	249.2	60	44.5	52.9	52.7	-0.2	-0.4	30	40	57.5	16
400-450	421.2	286.4	69	53	60.1	60.9	+0.8	+1.3	17	45	65.5	14
450-500	473.4	321.5	77	64	68.6	69.2	+0.6	+0.9	23	50	73.5	12
500-544	525.1	361.5	87	71	76.6	77.5	-1.1	-1.4	23	55	81.5	11

The growth of this dimension in the fetal period has been previously studied by Lafaille, Retzius, Corrado, Burtscher, Heuser, Friedenthal, Hasselwander, Fridolin, and others. Their findings are shown in table 179 and the upper group of curves in figure 63. When these averages are represented graphically, the resulting curves show considerable variation, particularly in their upper portions. Our calculated curve falls in the midst of this distribution approximating the values obtained by Retzius and by Heuser.

The use of this dimension in obstetrical procedure has led to an accumulation of considerable data on the length of the foot in the newborn. The chief published natal averages are given in table 152. Our calculated value for the newborn is lower than the observed value reported by most of these investigators. This is probably due to the fact that our measurement was made to the tip of the great toe rather than to the tip of the longest toe of the foot.

TABLE 152

AVERAGE LENGTH OF THE FOOT AT BIRTH

OBSERVER	AVERAGE BODY-LENGTH (cm)	AVERAGE LENGTH OF FOOT (cm)
Daffner (males)	....	7.83
Daffner (females)	....	7.81
Gönner	....	7.3–7.6
Hirst	....	8.0
Negri (males)	....	8.13
Negri (females)	....	7.43
Quetelet (males)	50.0	7.5
Quetelet (females)	49.6	7.4
Reicher	....	7.6
Schadow	46.8	7.8
Spitzy	....	7.8
Taylor (males)	51.2	8.3
Taylor (females)	50.0	8.1
Weissenberg (males)	50.8	7.8
Weissenberg (females)	50.0	7.8
Zeising	....	8.1
Present series (calculated)	50.2	7.4

69. Circumference of Thigh

(Field Graph 70, Table 153)

The circumference of the thigh was measured just below the gluteal sulcus in the horizontal plane. This dimension is increased 3.8 per cent by formalin injection. Subsequent immersion in formalin causes a further increase to 7.5 per cent in the first month, and to 8.6 in three months. Thereafter there is a slight decline to 7.5 per cent at six months.

Table 153 summarizes our findings and computations for this dimension. The average absolute deviations of the calculated from the observed values, for 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, are from about 3 to 4 mm. The corresponding relative deviations range from 3 to 5 per cent. The maximal absolute deviations are found in the 50 to 55 cm intervals, and are due largely to the correction for preservation artifacts.

We have found no published observations on the circumference of the thigh in the fetal period. Quetelet found the average circumference of the upper portion of the thigh in the newborn to be 13.8

cm for males (at 50.0 cm crown-heel length) and 13.7 cm for females (at 49.6 cm crown-heel length). He also found the circumference at the distal end of the thigh to be 11.7 cm for males, and 11.6 cm for females. Our calculated natal value is slightly higher, being 14.26 cm at 50.2 cm crown-heel length, when computed by means of the empirical formula with constants determined graphically.

TABLE 153

Circumference of Thigh
.31 CH (mm.) - 13.0 mm. (294 cases)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Circumference (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent		CH Length (cm.)	Value (mm.)	Per cent. increment
23-50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	84.8	62.8	19	10	15.7	13.3	-2.4	-15.3	14	10	18.0	—
100-150	124.4	88.5	36	17	26.0	25.6	-0.4	-1.5	41	15	33.5	86
150-200	172.5	118.9	49	29	40.6	40.5	-0.1	-0.2	26	20	49.0	46
200-250	224.5	151.7	69	42	57.0	56.6	-0.4	-0.7	47	25	64.5	32
250-300	271.4	182.0	90	55	69.1	71.1	+2.0	+2.9	42	30	80.0	24
300-350	326.4	220.3	115	77	88.4	88.2	-0.2	-0.2	32	35	95.5	19
350-400	370.9	249.3	116	87	99.5	102.0	+2.5	+2.5	29	40	111.0	16
400-450	421.2	286.4	142	99	116.6	117.6	+1.0	+0.9	17	45	126.5	14
450-500	473.4	321.5	165	112	141.8	133.8	-8.0	-5.6	23	50	142.0	12
500-544	525.1	361.5	203	140	168.5	149.8	-18.9	-11.2	23	55	157.5	11

70. Circumference of Calf

(Field Graph 69, Table 154)

This measurement represents the maximum circumference of the calf in the horizontal plane. We have no correction figures for the effect of artifacts on this dimension, but presumably the artifactual changes are similar to those of the thigh, which have just been described.

A summary of our findings and computations for this diameter is shown in table 154. Considering that this is a soft-part measurement, the agreement between the observed and calculated values for the 5 cm intervals of crown-heel length from 5 to 55 cm, inclusive, is a rather close one. The average absolute deviations are all below 2.5 mm. The corresponding average relative deviations range from about 2.7 to 5.4 per cent. The largest deviations are in the upper 5 cm intervals and probably are due largely to formalin artifacts.

We have no data on the growth of this dimension in the fetal period. Quetelet obtained an average natal circumference of 9.8 cm for males (at 50.0 cm crown-heel length) and 9.7 cm for females (at 49.6 cm crown-heel length). Our calculated natal value (at 50.2 cm crown-heel length, as estimated with the empirical formula having graphically determined constants) is 10.0 cm.

TABLE 154

CIRCUMFERENCE OF CALF
.22CH(MM.)-10.5MM.(289 CASES)

Crown Heel Length (mm.)		Crown Rump Length (mm.)	Circumference of Calf (mm.)				Difference between (a) and (b)		Number of cases	Calculated Values at 5 cm. Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)						
Range	Mean		Max.	Min.	Mean (a)		mm.	Per cent.		C H Length (cm.)	Value (mm)	Per cent. increment
23- 50	—	—	—	—	—	—	—	—	—	—	—	—
50-100	82.0	62.0	11	8	9.5	7.0	-2.5	-26.3	2	10	11 5	—
100-150	125.5	89.2	22	11	16.6	16.6	±0.0	±0.0	39	15	22.5	96
150-200	172.5	118.9	31	19	25.5	27.0	+1.5	+ 5.9	26	20	33 5	49
200-250	224.5	151.7	49	28	38.3	384	+0.1	+ 0.3	47	25	44.5	33
250-300	271.4	182.0	64	36	48.5	48.7	+0.2	+ 04	42	30	55.5	25
300-350	326.1	220.0	90	49	63.5	60.7	-2.8	-4.4	31	35	66.5	20
350-400	370 9	246.9	83	58	70.0	70.6	+0.6	+ 0.9	29	40	77.5	17
400-450	421.2	286.4	102	62	81.8	81.7	-0.1	- 0.1	17	45	88.5	14
450-500	473.4	321.5	112	78	98.0	93.1	-4.9	- 5.0	23	50	99.5	12
500-544	525.1	361 5	138	94	115.9	104.5	-11.4	- 9.8	23	55	110.5	11

III. Résumé and Discussion of Findings on the External Dimensions of the Lower Extremity

The empirical formulae for the dimensions of the lower extremity, like those of the upper extremity, all show negative *b* or secondary constants. As in the case of the upper extremity, these constants increase in size proximo-distally, with the exception of that of the foot height which is smaller than that of the leg length. This rule does not hold true for the thigh and calf circumferences, for the *b* constant of the latter is smaller than that of the former.

The calculated values for this group of dimensions at each 5 cm interval of crown-heel length, from 5 to 50 cm, inclusive, are summarized in table 155, and are shown graphically in figure 64. They are also included in the tables of the individual measurements (tables 144, 146, 147, 148, 150, 151, 153, and 154), which contain as well the absolute and percentage increments in these dimensions for each 5 cm interval of crown-heel length.

TABLE 155

CALCULATED VALUES OF THE EXTERNAL DIMENSIONS OF THE LOWER EXTREMITY AT EACH FIVE-CENTIMETER INTERVAL OF CROWN-HEEL LENGTH

Dimension	Formulae		Calculated values (mm.) at crown-heel lengths of:									
	a	b	5 cm.	10cm.	15cm.	20cm.	25cm.	30 cm.	35cm.	40cm.	45cm.	50cm.
Length of lower extremity	.43	- 7.0	14.5	36.0	57.5	79.0	100.5	122.0	143.5	165.0	186.5	208.0
Thigh length (post. sup. iliac spine to knee)	.25	- 2.0	10.5	23.0	35.5	48.0	60.5	73.0	85.5	98.0	110.5	123.0
" " (trochanter to knee)	.19	- 2.0	7.5	17.0	26.5	36.0	45.5	55.0	64.5	74.0	83.5	93.0
Leg length (knee to lateral malleolus)	.2	- 4.5	5.5	15.5	25.5	35.5	45.5	55.5	65.5	75.5	85.5	95.5
Foot height	.04	- 1.5	0.5	2.5	4.5	6.5	8.5	10.5	12.5	14.5	16.5	18.5
" length	.16	- 6.5	1.5	9.5	17.5	25.5	33.5	41.5	49.5	57.5	65.5	73.5
Thigh circumference	.31	-13.0	2.5	18.0	33.5	49.0	64.5	80.0	95.5	111.0	126.5	142.0
Calf circumference	.22	-10.5	0.5	11.5	22.5	33.5	44.5	55.5	66.5	77.5	88.5	99.5

Table 156 gives the computed values (as determined from the formulae obtained by graphic methods) of each of the external dimensions of the lower extremity at the close of each month of the et al period, and figure 65 illustrates the growth of these dimensions fn relation to time.

TABLE 156

CALCULATED VALUES OF THE EXTERNAL DIMENSIONS OF THE LOWER EXTREMITY AT THE CLOSE OF EACH MONTH OF THE FETAL PERIOD

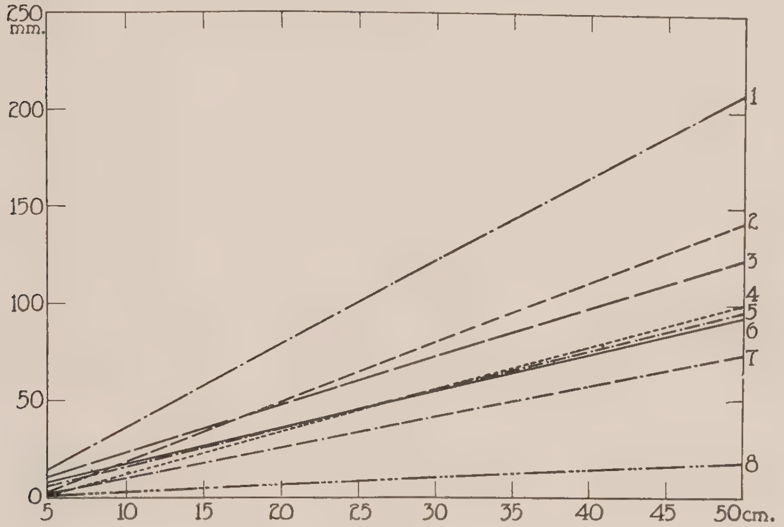
Dimension	Formulae		Calculated values (mm.) at:							
	a	b	3mo.	4mo.	5mo.	6mo.	7mo.	8mo.	9mo.	10mo.
Length of lower extremity	.43	- 7.0	23.4	59.8	91.0	118.6	143.7	166.8	188.5	208.9
Thigh length (post. sup. iliac spine to knee)	.25	- 2.0	15.7	36.9	55.0	71.0	85.6	99.1	111.7	123.5
" " (trochanter to knee)	.19	- 2.0	11.5	27.5	41.3	53.5	64.6	74.8	84.4	93.4
Leg length (knee to lateral malleolus)	.2	- 4.5	9.7	26.6	41.1	53.9	65.6	76.4	86.4	95.9
Foot height	.04	- 1.5	1.3	4.7	7.6	10.2	12.5	14.7	16.7	18.6
" length	.16	- 6.5	4.8	18.4	30.0	40.2	49.6	58.2	66.3	73.8
Thigh circumference	.31	-13.0	8.9	35.2	57.6	77.5	95.7	112.3	128.0	142.6
Calf circumference	.22	-10.5	5.1	23.7	39.6	53.7	66.6	78.4	89.5	99.9

The absolute and percentage increments of each of these dimensions in each month are given in tables 157 and 158. In the fourth month these values range from 36.4 mm for the length of the lower extremity to 3.4 mm for the foot height. These increments decline to 20.3 and 1.9 mm, respectively, for these dimensions in the tenth month.

In the fourth fetal month all of the linear dimensions of the lower extremities are more than doubled, the percentage increment figures ranging from 135.0 for the length of the thigh (from the posterior superior iliac spine to the knee) to 281.3 for the length of the foot. During this month the thigh circumference increases nearly threefold and the calf circumference more than three and one-half times. In the seventh fetal month the increments vary from 20.6 per cent for the thigh length to 24.0 per cent for the calf circumference. The increments in the tenth month are about one-half those of the seventh, ranging from 10.6 per cent for the thigh length to 11.6 per cent for the calf circumference.

FIGURE 64

THE GROWTH OF THE EXTERNAL DIMENSIONS OF THE LOWER EXTREMITY (AS DETERMINED BY EMPIRICAL FORMULAE) IN THE FETAL PERIOD WITH RESPECT TO GROWTH IN CROWN-HEEL LENGTH



Abscissa: Crown-heel length (cm). Ordinates: External dimensions of the lower extremity (mm).

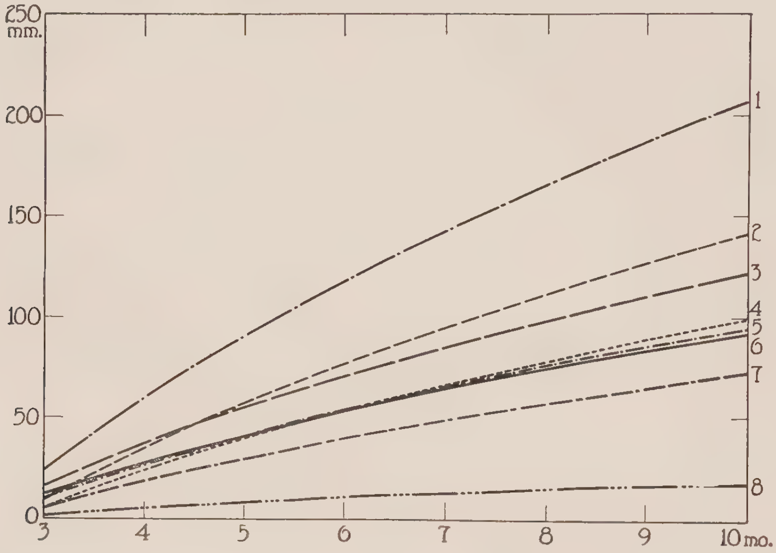
1. Length of lower extremity
2. Circumference of thigh
3. Length of thigh (posterior superior iliac spine to knee)
4. Circumference of calf
5. Length of leg
6. Length of thigh (trochanter to knee)
7. Length of foot
8. Height of foot

The per cent of the natal value that each dimension has attained at each 5 cm interval of crown-heel length is shown in table 159. At 5 cm these values for the linear dimensions vary from 8.5

per cent for the thigh length (posterior superior iliac spine to the knee) to 2.0 per cent for the length of the foot. At this stage the thigh circumference has attained 1.8 per cent and the calf 0.5 per cent of the natal size. At 25 cm crown-heel length all of the external dimensions of the lower extremity have completed somewhat less than half of their total prenatal growth, the figures ranging from 44.7 per cent for calf circumference to 49.2 per cent for the thigh length. At 45 cm the various dimensions have acquired slightly less than nine-tenths of the natal value, the figures ranging from 88.9 per cent for the calf circumference to 89.8 per cent for the thigh length.

FIGURE 65

The Growth of the External Dimensions of the Lower Extremity (as Determined by Empirical Formulae) with Respect to Age in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: External dimensions of the lower extremity (mm).

1. Length of lower extremity
2. Circumference of thigh
3. Length of thigh (posterior superior iliac spine to knee)
4. Circumference of calf
5. Length of leg
6. Length of thigh (trochanter to knee)
7. Length of foot
8. Height of foot

At three fetal months the length of the lower extremity is 11.2 per cent of its natal value, while the corresponding figures for its various linear segments range from 12.7 per cent for the thigh length (posterior superior iliac spine to knee) to 6.5 per cent for the length of the foot. At this time the thigh circumference has attained 6.2 per cent and the calf circumference 5.1 per cent of the natal size. At six months all of the dimensions of the lower extremity have completed over half of their prenatal growth. The values range from 53.8 per cent for the calf circumference to 57.5 per cent for the thigh length (posterior superior iliac spine to knee). At nine months all the dimensions have attained approximately nine-tenths of their natal size, the range being from 89.6 per cent for the calf cir-

TABLE 157

Calculated Absolute Increments of the External Dimensions of the Lower Extremity in Each Month of the Fetal Period

Dimension	Absolute increments (mm.) in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Length of lower extremity	36.4	31.2	27.6	25.2	23.1	21.7	20.3
Thigh length (post. sup. iliac spine to knee)	21.2	18.1	16.0	14.6	13.5	12.6	11.8
" " (trochanter to knee)	16.1	13.8	12.2	11.1	10.2	9.6	9.0
Leg length (knee to lateral malleolus)	16.9	14.5	12.8	11.7	10.8	10.1	9.5
Foot height	3.4	2.9	2.6	2.3	2.2	2.0	1.9
" length	13.5	11.6	10.3	9.4	8.6	8.1	7.6
Thigh circumference	26.2	22.5	19.9	18.1	16.7	15.6	14.7
Calf circumference	18.6	16.0	14.1	12.9	11.8	11.1	10.4

TABLE 158

Calculated Percentage Increments of the External Dimensions of the Lower Extremity in Each Month of the Fetal Period

Dimension	Percentage increments in the:						
	4th mo.	5th mo.	6th mo.	7th mo.	8th mo.	9th mo.	10th mo.
Length of lower extremity	155.6	52.2	30.3	21.2	16.1	13.0	10.8
Thigh length (post. sup. iliac spine to knee)	135.0	49.1	29.1	20.6	15.8	12.7	10.6
" " (trochanter to knee)	140.0	50.2	29.5	20.7	15.8	12.8	10.7
Leg length (knee to lateral malleolus)	174.2	54.5	31.1	21.7	16.5	13.2	11.0
Foot height	261.5	61.7	34.2	22.5	17.6	13.6	11.4
" length	281.3	63.0	34.3	23.4	17.3	13.9	11.5
Thigh circumference	294.4	63.9	34.5	23.4	17.5	13.9	11.5
Calf circumference	364.7	67.5	35.6	24.0	17.7	14.2	11.6

cumference to 90.4 per cent for the thigh length (trochanter to knee).

The computed relative sizes of external dimensions of the lower extremity at various body-lengths are shown in table 161. At 5 cm crown-heel length, the lower extremity as a whole forms 29 per cent of the total or crown-heel body-length; at 25 cm, 40.2 per cent; and at 50 cm, 41.6 per cent. Between 5 and 50 cm crown-heel length, the relative length of the thigh (trochanter to knee) increases from 15.0 to 18.6 per cent; that of the leg from 11.0 to 19.1 per cent; and that of the foot from 3.0 to 14.7 per cent. Between these two stages the

TABLE 159

Per Cent of Natal Value Attained by Each External Dimension of the Lower Extremity at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Percentage of natal value at crown-heel lengths of:									
	5cm.	10cm.	15cm.	20cm.	25cm.	30cm.	35cm.	40cm.	45cm.	50cm.
Length of lower extremity	7.0	17.3	27.6	38.0	48.3	58.7	69.0	79.3	89.7	100.0
Thigh length (post. sup. iliac spine to knee)	8.5	18.7	28.9	39.0	49.2	59.3	69.5	79.7	89.8	100.0
" " (trochanter to knee)	8.1	18.3	28.5	38.7	48.9	59.1	69.4	79.6	89.8	100.0
Leg length (knee to lateral malleolus)	5.8	16.2	26.7	37.2	47.6	58.1	68.6	79.1	89.5	100.0
Foot height	2.7	13.5	24.3	35.1	45.9	56.8	67.6	78.4	89.2	100.0
" length	2.0	12.9	23.8	34.7	45.6	56.5	67.3	78.2	89.1	100.0
Thigh circumference	1.8	12.7	23.6	34.5	45.4	56.3	67.3	78.2	89.1	100.0
Calf circumference	0.5	11.6	22.6	33.7	44.7	55.8	66.8	77.9	88.9	100.0

TABLE 160

Per cent of Natal Value Attained by Each External Dimension of the Lower Extremity at the Close of Each Month of the Fetal Period

Dimension	Percentage of natal value at:							
	3mo.	4mo.	5mo.	6mo.	7mo.	8mo.	9mo.	10mo.
Length of lower extremity	11.2	28.6	43.5	56.8	68.8	79.8	90.2	100.0
Thigh length (post. sup. iliac spine to knee)	12.7	29.9	44.5	57.5	69.3	80.2	90.3	100.0
" " (trochanter to knee)	12.3	29.4	44.2	57.3	69.2	80.1	90.4	100.0
Leg length (knee to lateral malleolus)	10.1	27.7	42.9	56.2	68.4	79.7	90.1	100.0
Foot height	7.0	25.3	40.9	54.8	67.2	79.0	89.8	100.0
" length	6.5	24.9	40.7	54.5	67.2	78.9	89.8	100.0
Thigh circumference	6.2	24.7	40.4	54.3	67.1	78.8	89.8	100.0
Calf circumference	5.1	23.7	39.6	53.8	66.7	78.5	89.6	100.0

thigh circumference makes an increase of nearly sixfold in relative size and the calf circumference an increase of nearly twentyfold.

The relative sizes of the external dimensions of the lower extremity at the close of each month of the fetal period are shown in table 162, and figure 66. At three months the lower extremity forms approximately one-third of the total or crown-heel body-length (33.1 per cent); at six months, approximately two-fifths (40.6 per cent); and at ten months, a little over two-fifths (41.6 per cent). The increase in relative length of the thigh is comparatively small. The leg,

TABLE 161

Relative Size of the External Dimensions of the Lower Extremity (Computed as Per Cents of the Crown-Heel Length) at Each Five-Centimeter Interval of Crown-Heel Length

Dimension	Per cent. of total (crown-heel) length at:									
	5 cm.	10 cm.	15 cm.	20 cm.	25 cm.	30 cm.	35 cm.	40 cm.	45 cm.	50 cm.
Length of lower extremity	29.0	36.0	38.3	39.5	40.2	40.7	41.0	41.3	41.4	41.6
Thigh length (post. sup. iliac spine to knee)	21.0	23.0	23.7	24.0	24.2	24.3	24.4	24.5	24.6	24.6
" " (trochanter to knee)	15.0	17.0	17.7	18.0	18.2	18.3	18.4	18.5	18.6	18.6
Leg length (knee to lateral malleolus)	11.0	15.5	17.0	17.8	18.2	18.5	18.7	18.9	19.0	19.1
Foot height	1.0	2.5	3.0	3.3	3.4	3.5	3.6	3.6	3.7	3.7
" length	3.0	9.5	11.8	12.8	13.4	13.8	14.1	14.4	14.6	14.7
Thigh circumference	5.0	18.0	22.3	24.5	25.8	26.7	27.3	27.8	28.1	28.4
Calf circumference	1.0	11.5	15.0	16.8	17.8	18.5	19.0	19.4	19.7	19.9

TABLE 162

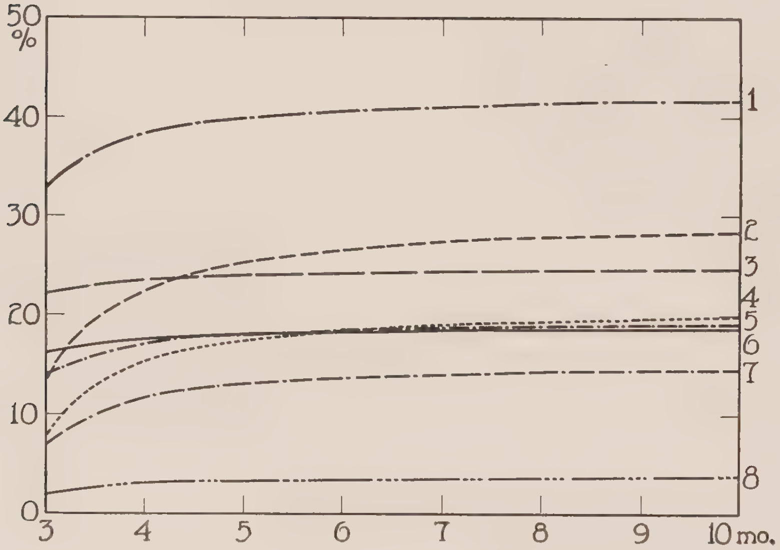
Relative Size of the External Dimensions of the Lower Extremity (Computed as Per Cents of the Crown-Heel Length) at the Close of Each Month of the Fetal Period

Dimension	Per cent. of total (crown-heel) length at:							
	3 mo.	4 mo.	5 mo.	6 mo.	7 mo.	8 mo.	9 mo.	10 mo.
Length of lower extremity	33.1	38.5	39.9	40.6	41.0	41.3	41.5	41.6
Thigh length (post. sup. iliac spine to knee)	22.2	23.7	24.1	24.3	24.4	24.5	24.6	24.6
" " (trochanter to knee)	16.2	17.7	18.1	18.3	18.4	18.5	18.6	18.6
Leg length (knee to lateral malleolus)	13.7	17.1	18.0	18.5	18.7	18.9	19.0	19.1
Foot height	1.8	3.0	3.3	3.5	3.6	3.6	3.7	3.7
" length	6.8	11.8	13.2	13.8	14.2	14.4	14.6	14.7
Thigh circumference	12.6	22.7	25.3	26.5	27.3	27.8	28.2	28.4
Calf circumference	7.2	15.3	17.4	18.4	19.0	19.4	19.7	19.8

however, shows an increase in relative length of nearly one-half (from 13.7 per cent at three months to 19.1 per cent at birth). The foot height is nearly doubled in relative size in the fetal period, rising from 1.8 per cent of the crown-heel length at three months to 3.7 per cent at birth, and the length of the foot is more than doubled in the fetal period (from 6.8 per cent at three months to 14.7 per cent at birth). The relative sizes of both the circumference of the thigh and of the calf show increases of considerably over 100 per cent between three fetal months and birth.

FIGURE 66

The Changes in the Relative Size of the Dimensions of the Lower Extremity in the Fetal Period



Abscissa: Age in fetal or lunar months (as determined from the crown-heel length by the empirical formula of Scammon and Calkins). Ordinates: Relative values of the dimensions of the lower extremity expressed as per cents of the crown-heel length.

1. Length of lower extremity
2. Circumference of thigh
3. Length of thigh (posterior superior iliac spine to knee)
4. Circumference of calf
5. Length of leg
6. Length of thigh (trochanter to knee)
7. Length of foot
8. Height of foot

In the preceding paragraph we have considered the relations of the length of the lower extremity to the body as a whole and we may now consider its relations to some other major divisions of the body. The relation of the length of the lower extremity to the sitting-height may be estimated by a modified skelic index computed by dividing the former dimension by the latter and multiplying the result by 100. This index stands at 38.2 at 5 cm crown-heel length, at 59.1 at 25 cm, and at 62.1 at 50 cm. It is 45.3 at three fetal months, 60.0 at six months, and 62.1 at birth.

The relation of the lower extremity to the trunk may be expressed by an index computed by dividing the length of the lower extremity by the trunk length (distance from sternal notch to pubis) and multiplying the result by 100. The values for this index are 93.5 at 5 cm crown-heel length, 140.6 at 25 cm, and 132.2 at 50 cm. Computed for intervals of time, the values are 109.9 at three months, 142.4 at six months, and 132.2 at ten months or birth. Thus it appears that the lower extremities grow in length more rapidly in the first part of the fetal period, and more slowly in the second part. We think it very probable, however, that this difference is only an apparent one, due to the fact that trunk length seems to be affected by posture.

When we compare the length of the upper extremity with that of the lower extremity, using the intermembral index computed by dividing the length of the upper extremity by the length of the lower extremity and multiplying the result by 100, we obtain values of 110.3 at 5 cm crown-heel length, 95.5 at 25 cm, and 94.2 at 50 cm. When computed for intervals of time, this index is 103.8 at three months, 95.1 at six months, and 94.2 at ten months. In other words, the growth of the inferior extremity exceeds that of the superior in the fetal period. The members are of about equal length at 7 cm, or early in the fourth fetal month. The general trend of this index is similar to that found by Reicher and by Schultz, but our values are much lower.

A second intermembral index is computed by dividing the combined length of the arm and forearm by the combined length of the thigh and leg and multiplying the result by 100. The values obtained by this procedure are 94.6 at 5 cm crown-heel length, 76.2 at 25 cm, and 74.5 at 50 cm; or, for intervals of time, 85.8 at three months, 75.7 at six months, and 74.5 at ten months. Thus this index shows the same general character as does the preceding one, although the combined lengths of the two proximal segments of the upper extremity are never equal to the combined lengths of the two proximal segments of the lower extremity, in the fetal period.

The relation of the length of the leg and the length of the thigh in the fetal period may be expressed by the tibio-femoral index, computed by dividing the length of the leg by the length of the thigh (trochanter to knee), and multiplying by 100. This index is 73.3 at 5 cm crown-heel length, 100.0 at 25 cm, and 102.7 at 50 cm; or, 84.3 at three months, 100.7 at six months, and 102.7 at birth. The trend of this index is similar to that reported by Reicher and by Schultz, but our values are distinctly higher.

The relation of the length of the leg to that of the foot may be expressed by dividing the foot length by the leg length and multiplying the result by 100. The value of this index is 27.3 at 5 cm, 73.6 at 25 cm, and 77.0 at 50 cm crown-heel length. It is 49.5 at three fetal months, 74.6 at six months, and 77.0 at birth. Again, the trend of this index is in agreement with the findings of Reicher and of Schultz. Evidently the length of the foot is increasing relatively much more rapidly than that of the leg, and that of the leg more rapidly than that of the thigh in the early part of the fetal period.

The relation between the girths of the various parts of the lower extremity can be expressed by the leg-proportion index, which is found by dividing the circumference of the calf by the circumference of the thigh and multiplying the result by 100. The values of this index are 20.0 at 5 cm crown-heel length, 69.0 at 25 cm, and 70.1 at 50 cm. At three fetal months this index is 57.3, while at six months it is 69.3, and at birth it is 70.1. Thus the girth of the leg increases much more rapidly than that of the thigh, particularly at the early part of the fetal period.

PART IX

GENERAL DISCUSSION

I. The Growth of the External Bodily Dimensions with Respect to the Total Body-Length

In our opinion the most important conclusion reached in this study is that concerning the interrelationships of the growth of the various external dimensions of the body in the fetal period. As we have pointed out in the preceding sections of this publication, the great majority of these dimensions show a rectilinear relationship to the total or crown-heel body-length, and, since they are so related to this value they bear the same general relationship to one another.

This relationship is quite evident for practically all dimensions of the body in the interval between 5 and 35 cm total body-length. It is also characteristic of the great majority of the other external dimensions, between 35 and 50 cm crown-heel length, if the various artifacts introduced by formalin preservation and natal changes in the body are eliminated. The only exceptions to this rule are certain dimensions in the median line of the ventral surface of the body which, we think, are affected by posture. In this connection we may point out that the observations of other investigators on these median line dimensions usually tend to follow the course of a straight line when plotted against the total or crown-heel length.

Since these relationships appear graphically as straight lines, they may be expressed algebraically by the general formula:

$$D = aL + b,$$

where D is any external dimension of the body, L is the total or crown-heel body-length, a is an empirical constant in the form of a positive decimal fraction, and b is another empirical constant that may be either positive or negative.

In such an expression the constant a represents the slope of the line in question and the constant b represents the elevation or depression of this line above the abscissa at its intercept. In other words a represents the *absolute rate* of growth in the dimension with respect to the growth in body-length in the period under consideration, and it may be determined by the expression:

$$\frac{D_2 - D_1}{L_2 - L_1},$$

where L_1 and L_2 are any two given successive crown-heel lengths and D_1 and D_2 are values for any given dimension at these lengths.

The constant b, on the other hand, gives no information regarding the absolute rate of growth in the interval or period of body-length under consideration, but, in conjunction with a, it indicates the *amount* of growth that has taken place prior to the period for which the formula holds good. If b is positive we may say that the amount of growth in the dimension has been equal to the sum of the growth at rate a and of the b value. Under these conditions the growth of the dimension has been greater in this earlier period of crown-heel length increase than it is for an equal interval of crown-heel length growth in the period under consideration. If the b constant is a negative one the amount of growth of the dimension is equal to the amount of growth at rate a, minus the value b. In this instance the increase in the dimension with respect to the total body-length in the period prior to that under consideration has been less than it is for an equal interval of crown-heel length in the period under consideration.

In the present instance the term "embryonic period" may be used as the approximate equivalent of the "period prior to that under consideration," and the term "fetal period" in place of the "period under consideration." Therefore we may restate the conclusions of the preceding paragraph in more general terms and say that external bodily dimensions represented by formulae with positive b constants increase more, with respect to body-length, in the embryonic period than in any equal interval of length-increase in the fetal period. Conversely, dimensions with negative b constants show less increment with respect to body-length. Dimensions with zero b constants make equal increments with respect to total body-length in the embryonic period and in equal body-length intervals of the fetal period.*

These points may be illustrated by examples of three types of straight line formulae. The empirical expression for the suboccipito-frontal circumference of the head, as determined by graphic methods, is:

$$SFC\ (\text{mm}) = 0.65\ CH\ (\text{mm}) + 15.0\ (\text{mm}),$$

---

* Since the b constant is only a part of the measure of the *total amount of growth* in the embryonic period and it gives us no key as to the *rate of growth* at this time, we cannot say that, the a constants being equal, a positive b constant indicates more rapid early growth than a negative one, for we cannot tell from such an expression when the growth of any dimension in question begins, and the size of a positive constant may be associated either with a more rapid rate of growth or with a longer period of growth.

which indicates that during the interval from 50 to 500 mm crown-heel length, there is a gain of 6.5 mm in suboccipital circumference for each increment of 10 mm in crown-heel length. But at 50 mm crown-heel length, which forms the lower limit of the application of this formula and approximates the close of the transition stage from the embryonic to the fetal period, the value for this dimension will be 0.65 (50 mm) +15.0 mm or 47.5 mm. In other words this dimension of the head has grown 47.5 mm during the period in which the first 50 mm of growth in crown-heel length took place, although after this period there will be an increase of only 32.5 mm for each succeeding 50 mm increment in total body-length.

On the other hand, the empirical formula for the length of the upper extremity, as determined by graphic methods, is:

$$UEL\ (\text{mm}) = 0.4\ CH\ (\text{mm}) - 4.0\ (\text{mm}).$$

This indicates that between 50 and 500 mm crown-heel length there will be a gain of 4 mm in the length of the upper extremity for each 10 mm increment in body-length. But our calculated value at 50 mm is 0.4 (50 mm) −4.0 mm, or, 16 mm. In other words the total growth in length of the upper extremity in the interval of growth in the body-length to 50 mm is only 16 mm, whereas the increments in this dimension for each succeeding 50 mm of crown-heel length will be 20 mm.

The formula for the circumference of the thorax at the nipples, as determined by graphic methods, is:

$$CTN\ (\text{mm}) = 0.6\ CH\ (\text{mm}) \pm 0\ (\text{mm}).$$

There is, therefore, an increase of 6 mm in this dimension for every increment of 10 mm in body-length between 50 and 500 mm. Since the second or *b* constant is zero in this instance the value of the dimension at 50 mm crown-heel length is 30 mm. In other words, until the fetus reaches the length of 50 mm there has been a total growth of 30 mm in the chest circumference, and in each succeeding interval of 50 mm growth in crown-heel length there will also be a gain of 30 mm in chest circumference.

It should be clearly pointed out that these simple relationships apply strictly to the increase of the various dimensions with respect to one another (including the total or crown-heel length) and that they do not apply to growth with respect to time. It should also be understood that these straight line relationships do not obtain until the fetus is 3 cm or more in length, although they hold good from this stage to birth. How long they may be applied to the proportionate growth of the body in postnatal life cannot be definitely stated, although we have a large body of evidence indicating that they are characteristic of certain bodily dimensions for a considerable portion of infancy.

While these formulae indicate that the *absolute growth* of each external dimension bears a constant ratio to the absolute growth of the body-length in the fetal period, it does not follow that the relative proportions of the dimensions to the body-length remain constant during this time. These ratios will remain unchanged only in those instances where the second or b constant of the empirical formula is zero. In all other cases the relative size of the dimension will decrease if the b constant is positive, and will increase if the b constant is negative.

Since we have found that these dimensions are related to the body-length in a simple linear way, they are similarly related to one another, and therefore their interrelationships may be expressed by the general formula:

$$D_1 = a'D_2 + b',$$

where D_1 and D_2 are any two external dimensions of the body and a' and b' are empirical constants. If our observations were without "gratuitous variation," grouping effects, or artifactual error, it would follow that the formula for any dimension in the term of any other dimension could be derived from the formulae expressing their relations to crown-heel length. If, for example, the formula for a given dimension is:

$$D_1 = a_1L - b_1,$$

and the formula for the second dimension is:

$$D_2 = a_2L - b_2,$$

then,

$$L = \frac{D_1 + b_1}{a_1}, \quad L = \frac{D_2 + b_2}{a_2},$$

$$D_1 = a_1\frac{D_2 + b_2}{a_2} - b_1, \text{ and, } D_2 = a_2\frac{D_1 + b_1}{a_1} - b_2.$$

Since a_1, a_2, b_1, and b_2 are known constants, we may reduce these expressions to:

$$D_1 = a'D_2 + b'.$$

In practical work the gratuitous and artifactual errors, and the effect of grouping the observations for 5 cm intervals of crown-heel length, are sufficient to change the constants of these formulae somewhat when they are derived by this method, although such constants may be used for the larger and less variable dimensions with some confidence.

The conclusions regarding growth derived by this method of analysis may be summarized in two statements:

First, the growth of the external dimensions of the body in the fetal period is directly proportional to the linear growth of the body as a whole and that of other external dimensions of the body.

Second, the absolute growth rate of each external dimension of the body, with respect to the absolute linear growth rate of the body as a whole, is usually established when the fetus is between 3 and 10 cm in crown-heel length, and remains unchanged to birth.

It may be of interest to trace the growth of these concepts, for the idea of the simple linear relationship of the various external bodily dimensions to the body-length in the fetal period of man is not entirely new. The first indication of its recognition seems to be in a short paper on measuring human embryos by Mall in 1907. In this contribution he presents a table giving, in millimeters, the corresponding lengths of the vertebral column, the sitting-height (crown-rump length), and the standing-height (crown-heel length) in a series of specimens ranging from 20 to 550 mm in crown-heel length. Following the table is this statement:

> It may be seen by looking over this table that the spinal column increases 7 mm. in length, and the standing height 15 1/2 mm., every time the sitting height increases 10 mm. in embryos over 20 mm. in length. This continues until the sitting height has reached 300 mm. As the foetuses become larger and larger the growth of the legs is slightly more marked than before, and during the last month or six weeks of pregnancy the standing height increases 20 mm. while the sitting height increases 10 mm. The statement may therefore be made for embryos and foetuses from the end of the second month to the end of the eighth month, that the spinal column increases 7 mm. and the sitting height 10 mm., while the standing height increases 15 1/2 mm. This reduced to a formula reads as follows:
>
> $$\frac{\text{Spinal Column}-15}{7}=\frac{\text{Sitting Height}-20}{10}=\frac{\text{Standing Height}-23}{15\frac{1}{2}}$$
>
> The figures I have given make it possible to convert the standing height into the sitting height, an obstacle which has been difficult to overcome in estimating the age of embryos.

Using SC for the length of the spinal column, CR for the sitting-height (crown-rump length), and CH for the standing-height (crown-heel length), Mall's formula for these relations between 20 and 455 mm in crown-heel length may be written:

$$\frac{SC-15}{7}=\frac{CR-20}{10}=\frac{CH-23}{15\frac{1}{2}},$$

or, $0.143\ SC-2.14=0.10\ CR-2.00=0.0645\ CH-1.48,$
or, $0.143\ SC=0.0645\ CH+0.66,$
or, $SC=0.4510\ CH+4.62,$
and, $0.10\ CR=0.0645\ CH+0.52,$
or, $CR=0.645\ CH+5.2.$

Similarly Mall's expression for the relationship between the sitting-height (crown-rump length) and the standing-height (crown-heel length) for fetuses over 300 mm sitting-height or 455 mm standing-height may be written:

$$\frac{CR-300}{10}=\frac{CH-455}{20},$$

or, $0.1CR-30=0.05CH-22.75=0.05CH+7.25,$

or, $CR=0.5CH+72.5.$

Thus it will be seen that Mall was dealing with the straight line relationships between these three values, and that we may reduce his expressions to the common algebraic form for straight lines that we have given above.

Mall drew no general conclusions from this discovery, possibly because of the cumbersome algebraic form that he used for his expressions, nor did he attempt to apply it to other dimensions of the body. It is most curious that, while he included a large part of this preliminary paper almost verbatim in his final paper, which forms the eighth chapter of Keibel and Mall's *Human Embryology*, the particular section dealing with these numerical relationships was entirely omitted. This is the more striking since Mall's field graphs and curves (presumably drawn by inspection) for sitting-height, standing-height, and auriculo-rump distance in the fetal period, show this straight line relationship very clearly.

The subject seems to have attracted no further attention until one of us (Calkins) began a study in this field in 1919. At the 37th session of the American Association of Anatomists in March, 1921, the empirical formulae and curves for the seventy dimensions considered in this paper were presented. An abstract of this paper that included the following statement was published:

> External bodily dimensions plotted against body length, (being, in general, straight lines) are expressed by the empirical formula, $Y = aX \pm b$ (Y, dimension; X, body length; a and b, constants). The constant b is positive for the head, zero for the thorax, and negative for the abdomen, pelvis and extremities.
>
> It may be concluded: (1) The relative growth rates of the external body dimensions are established in the third month and remain unchanged until birth. (2) The growth of the external body dimensions in the fetal period follows the law of developmental direction.

In 1922, Calkins published a detailed account with field graphs and tabulations of ten dimensions of the head and the sitting-height and gave empirical formulae of the straight line type therefor. This material is included in the present paper, and was published in summary in *Papers from the Mayo Foundation for Medical Education and Research and the Medical School, University of Minnesota*, Volume 2 (for 1921–22, published in 1923).

In 1922, Noback, also working in this laboratory, developed a simple correlation formula for the relation between crown-rump and crown-heel length using the material of Mall, MacKeen, Michaelis, Taylor, and Weissenberg. Since his formula was intended for ready use in the laboratory, he used the expressions:

$$CH = \frac{3CR - 3}{2}, \text{ or, } CR = \frac{2CH + 3}{3}.$$

These, when reduced to the common algebraic form employed here, become:

$$CH = 1.5CR - 1.5, \text{ or, } CR = 0.666 \cdots CH + 1.0.$$

In the following year Arey published a series of simple formulae for the relation between crown-heel length and age, and crown-rump length and age. These are:

$$CH \times 0.2 = T, \text{ and, } CR \times 0.3 = T,$$

where CH and CR are the crown-heel and crown-rump lengths in centimeters and T is the age in months. From these expressions he evidently assumed the relation between the crown-heel and crown-rump length to be a straight line one that may be written:

$$CR = 0.666 \cdots CH, \text{ and, } CH = 1.5CR.$$

Arey has also made use of this relation in his more recent (1925) paper on this subject.

In 1924, Akiba published the results of a quantitative investigation of nine external dimensions of the body in the fetal period. The dimensions studied were the standing-height or crown-heel length (CH); the sitting-height or crown-rump length (CR); the distance from the eye to the occiput (AO); the length of the upper extremity (OE); the length of the lower extremity (UE); the length of the arm (OA); the length of the forearm (VA); the length of the thigh (OS); and the length of the leg (US). He found that the relations of these dimensions to the crown-rump length might be represented by straight lines for which he published formulae using the form of expression employed by Noback. His original formulae, together with their reduction to the common algebraic form employed in this paper and their computation in terms of the crown-heel (CH) length are as follows:

$CR=3/5\ CH+1=0.6\ CH+1.0,\ CH=5/3\ (CR-1)=1.666\cdots CR-1.666\cdots$
$OE=25/37(CR-1)=0.676\ CR-0.676$, or, $CR=37/25\ OE+1=1.48\ OE+1$.
$OA=3/11(CR-1)=0.273\ CR-0.273$, or, $CR=11/3\ OA+1=3.667A+1$.
$VA=5/21(CR-1)=0.238\ CR-0.238$, or, $CR=21/5\ VA+1=4.2\ VA+1$.
$UE=11/16(CR-2)=0.688\ CR-1.375$, or, $CR=16/11\ UE+2=1.45\ UE+2$.
$OS=4/11(CR-2)=0.364\ CR-0.727$, or, $CR=11/4\ OS+2=2.75\ OS+2$.
$US=1/3(CR-2)=0.333\cdots CR-0.667$, or, $CR=3\ US+2$.
$AO=4/11(CR)=0.364\ CR$, or, $CR=11/4\ AO=2.75\ AO$, or,
$OE=0.405\ CH,\ OA=0.164\ CH,\ VA=0.143\ CH,\ UE=0.413\ CH-0.688$.
$OS=0.218\ CH-0.364,\ US=0.2\ CH-0.333,\ AO=0.218\ CH+0.364$.

A summary of formulae for forty of the more important external dimensions of the body as determined by graphic methods, the method of averages, and the method of least squares, the residuals by these methods, and a résumé of conclusions derived from them, were published by the present writers in 1925.

These linear relationships of bodily dimensions to the total body-length and to each other are not confined to the exterior of the body alone. They have been found to be characteristic of certain dimensions of the central nervous system (Dunn '21, '26); the cornea and the optic nerve (Scammon and Armstrong '22, '25); the mandible (Scammon and Ganz '22); the majority of the dimensions of the respiratory system (Noback '23, '25); certain measurements of the nasal apparatus (Knapp '21); the vertebral column as a whole and its various segments (Calkins and Scammon '27); the individual vertebra (Calkins '23); certain parts of the digestive tube (Scammon and Kittelson '27); the dimensions of the pituitary body (Covell '27); the length of the uterus in its earlier fetal development (Scammon '25); and certain long bones (Hesdorffer and Scammon '28). Studies in progress in this laboratory at the present time indicate that this relationship holds true for a large number, although not all, of the linear dimensions of other internal portions of the body.

It may, therefore, be stated in conclusion that the rectilinear relationships of growth in the various external and internal parts of the body in the fetal period have been studied quantitatively by some twelve investigators and have been found to hold true for over one hundred and fifty different dimensions.

II. The Application of the Present Findings to the "Law of Developmental Direction"

A second point of general interest is the bearing that these studies have upon the "law of developmental direction" in prenatal life.

It has long been recognized that the development of the vertebrate embryo tends, in general, to proceed from the cephalic to the caudal pole of the body-stem, from the proximal to the distal segments of the extremities, and, possibly, from the dorsal to the ventral surfaces or regions of the body. This sequence of developmental processes has been variously termed the "law of craniocaudal development," the "law of cephalocaudal development," and the "law of developmental direction." The last term is perhaps the preferable one for it is the most inclusive.

The "law" has been defined by Jackson and Scammon as follows:

> While each part [of the body] passes through its own cycle of changes these changes as a whole tend to follow what is known as the *law of developmental direction*; for it is generally found that development (including growth and differentiation), in the long axis of the body, appears first in the head region of the body and progresses toward the tail region and similarly development in the transverse plane begins in the mid-dorsal region and progresses lateroventrally (in the limbs proximodistally).

The general features of this "law" have been known to embryologists for many years; in fact, as Jackson has pointed out, there is at least a suggestion of it in the sixth book of Aristotle's *De Animalia*, and a passage in the second book (chapter three, paragraph six) gives a still clearer indication of Aristotle's appreciation of it.

The phenomena that represent this "law" have been the subject of active discussion the past few years, particularly because of their interpretation in the light of the gradient theory of Child. In this connection one may call attention to the papers of Kingsbury ('24, '26) and of Child ('25) on the more general phases of the subject, and the experimental studies of Bellamy ('19) and Hyman ('21, '26, '27).

Although the general process is well known, no attempt seems to have been made to study it by the quantitative method. The present material furnishes data that may be used for this purpose.

It has been seen that the formulae for the great majority of the external dimensions of the body fall in three groups. First, those in which the second or the *b* constant is a positive one, second, those in which it is zero, and third, those in which it is negative. If these formulae for the various regions are examined in detail, it is found that of the 72 empirical expressions for the dimensions of the head and neck 69 have positive *b* constants. The exceptions consist of the bi-malar diameter, or distance, as determined by the method of least squares and the method of averages and the orbito-auricular distance as determined by the graphic method. Thus, in practically every instance, the dimensions of the cranial parts of the body show positive second or *b* constants indicating that they have made more growth with respect to body-length in the embryonic period than they do in any equal later period.

When the 79 empirical formulae for the dimensions of the trunk are examined, it is found that nearly two-thirds have positive *b* constants, nearly one-third have negative *b* constants, and the remainder have zero secondary constants. These formulae for the dimensions of the thorax or upper part of the trunk have either positive or zero *b* constants, whereas those involving the lower portion of the trunk have negative *b* constants in every instance. Thus the dimensions of the trunk show a graduation, those of the upper part have grown more with respect to body-length in the embryonic period than in the fetal period and therefore undergo a decrease in relative size in the latter; those in the middle portion have grown at approximately the same rate with respect to total body-length in both periods and maintain a constant ratio to the total body-length; while those of the lower portion have grown less with respect to total body-length in the embryonic period than in the fetal period and gain in size relative to body-length in the latter epoch of prenatal life.

The empirical formulae for the external dimensions of the pelvis all show negative b constants with the exception of that of the bi-tuberous distance, which has a zero b constant as determined by the graphic method. Thus the dimensions of the pelvis have grown less in the embryonic period than they do in an equal interval of length increase in the fetal period.

The dimensions of the extremities are represented by 48 formulae, only two of which have positive b constants (length of arm by the method of averages and the method of least squares). Furthermore, there is a distinct, although not invariable, tendency for the negative b constants to increase in absolute size as we follow the successive segments of the limbs proximo-distally.

While the examination with respect to sign of the b constants in these rectilinear formulae enables us to make a general classification of the dimensions of the body with respect to amounts of growth, their detailed classification is followed much more easily by the use of *length-interval ratios.* These ratios are made by comparing the amount of the dimensional growth of any part of the body for given and successive equal intervals of increase in crown-heel length. Any pair of consecutive and equal intervals of which the first takes origin at zero body-length might be employed for this ratio. But it is convenient to use as the first interval that from 0 to 5 cm crown-heel length, and for the second, that from 5 to 10 cm crown-heel length. In other words, a ratio may be established between the amount of growth taking place in a given dimension during the interval in which the embryo grows to a total length of 5 cm with the amount of growth that takes place in this dimension during the interval in which the embryo or fetus makes its second increment of 5 cm, or, while it increases from 5 to 10 cm in total or crown-heel length.

Obviously this ratio will be unity for the crown-heel length, for the relationship is:

$$5:(10-5)=5:5=1.$$

In the case of all other dimensions the absolute amount of growth attained at 5 cm will be:

$$aL+b \text{ or } a5+b,$$

and the absolute amount of growth occurring in the second interval will be:

$$(a10+b)-(a5+b)=a5.$$

The ratio between the two, therefore, is:

$$\frac{a5+b}{a5} \text{ or } 1+\frac{b}{a5}.$$

Evidently, if the absolute amount of growth of a dimension in the first 5 cm interval of crown-heel length is greater than that in the second, the ratio will be more than unity, while if the absolute amount of growth is greater in the second interval than in the first, the ratio will be less than unity.

Some of these ratios that have been determined for a number of series of external dimensions of the body may be examined. The first series deals with major dimensions in the longitudinal axis of the body-stem and with the extremities as a whole. The length-interval ratio for the distance from the crown to nasion is 1.91; that for the distance from crown to chin is 1.59; that from crown to sternal notch, 1.34; that for crown to umbilicus, 1.26; that from crown to rump, 1.14; and that from crown to heel, 1.00. The ratio for the total length of the upper extremity is 0.83 and for the total length of the lower extremity, 0.66. It will be seen that there is a successive decrease in the size of the length-interval ratio proceeding from the cranial to the caudal pole of the body and extending to the extremities. In other words, the more the caudal portion of the body is included in the dimension, the smaller is the ratio, or those portions of the body that are more cranially or proximally placed make a larger amount of growth in the first 5 cm interval of body-length increase than they do in the second or any succeeding equal body-length interval.

A second series of length-interval ratios shows these changes in the circumferences of the head and trunk. They are as follows: horizontal head circumference, 1.40; circumference of the neck, 1.24; circumference of the chest at the level of the nipples, 1.06; circumference at the level of the tenth rib, 1.08; and circumference of the abdomen at the umbilicus, 0.80. Here again it will be seen that the length-interval ratios of the girths decline as they pass from the cranial to the caudal pole of the body. However, the series is not entirely consistent, for the circumference of the chest at the nipples shows a smaller length-interval ratio than do the circumferences at the tenth rib, or the xiphi-sternal junction. This discrepancy may be due to the changes in chest form which occur within a slight degree of respiration and which are apt to produce artifacts in all chest girths.

The length-interval ratios of the various linear dimensions of the upper extremity are: length of arm, 1.04; of forearm, 0.92; of hand, 0.39; and of middle finger, 0.25. The corresponding ratios for the lower extremity are: length of thigh, 0.82; of leg, 0.66; and of foot, 0.23. It will be seen that these ratios undergo a consistent reduction from the proximal to the distal portions of the limbs.

We think that these data offer adequate quantitative proof of the common presence of the sequence known as the "law of developmental direction," in the prenatal period of human development.

III. Dimensional Growth with Respect to Age in the Fetal Period

The conclusions drawn in this study are based mainly on the relations observed between the various external dimensions of the body and particularly on the relationship that each dimension bears to the total or crown-heel length. It is also of interest to attempt some analysis of the growth of these dimensions with respect to time in the fetal period. While the results of such analysis must be regarded as tentative because of the uncertainty of our data on fetal age, a summary of the present status of the subject is desirable, and it is probable that certain general conclusions may be drawn that will remain valid.

If the various sets of modern data on fetal age and body-length in prenatal life, such as those of Heuser ('12), Mall ('10), Reicher ('23), Streeter ('20), and Zangemeister ('11), and the values of the combination tables of Lange ('03), and Ylppö ('19), are plotted with age as abscissa and body-length as ordinate, they appear, in the great majority of instances, as asymmetric sigmoid curves.

These curves indicate a slow absolute rate of linear growth in the early embryonic period, followed by a rapid increment in the middle third of prenatal life, and thereafter by a slow decline in growth rate to birth. The sigmoid curve of prenatal lineal growth has been recognized. It is suggested at least by the first published graph of prenatal linear growth (by Toldt in 1879), and typical representations of it may be found in the publications of Mall ('10), Meyer ('14, '15), Stratz ('09), Thompson ('17), Zangemeister ('11), and a number of other investigators. Curves having the same general form have also been developed for the ponderal growth of the body in prenatal life and infancy.

This type of curve is not peculiar to human growth. It has been found to be characteristic of the linear and ponderal growth with respect to time of many of the lower animals, the linear growth of some plants, and it is, in fact, typical of many forms of organic increment besides the growth of individuals.

We are probably justified in assuming that some curve of this general type will eventually be found to be an adequate one for expressing the phenomenon of the prenatal linear growth of the human body, and that its analytic expression, when sufficient data are available, may be made along the lines recently developed by Pearl and Reed ('25) for asymmetric curves of this nature. In the meantime, since our data on the linear growth of the body in the early part of prenatal life are not entirely satisfactory either in quantity or quality, it is probably sufficient to develop empirical formulae that will serve as conventions for the *latter* or *upper* segment of the progression involving the relation between age and body-length in the fetal period proper, with which we are particularly concerned.*

A number of attempts have been made to develop such expressions. For convenience in discussion these may be arranged in three groups: the simple rectilinear formulae, the phased formulae, and the simple curvilinear formulae.

It seems to have been a common opinion among the earlier embryologists and obstetricians that the relation between the body-length of the fetus and its age was a simple rectilinear one. The earliest quantitative expression of this relation that we have encountered is that of Caspar ('54), who laid down the rule that the age of the fetus in lunar months equals one-fifth of the length in centimeters, or:

$$T = 0.2L,\ L = 5T,$$

where T is the age in lunar months and L is the body-length in centimeters.†

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* Since the above was written, a "semirational" formula for the linear growth of the body with respect to time in prenatal life has been presented by Scammon, Dunn, and Ness ('29). This expression is based upon the saturation curve, a form of curve resulting from the generalization of the logistic, developed by Reed ('25). The values for the *fetal period proper* given by this "semirational" formula are not significantly different from those obtained from the empirical formula of Scammon and Calkins ('23) used in the present study.

† Quetelet, in 1836, noted that his empirical expression for the linear growth of the body between birth and maturity also held for the latter part of prenatal life, but he made no attempt to develop a specific formula for the fetal period.

Boulton ('76) found that the length of the fetus at twelve weeks is 3 inches and that there is a gain of 2.5 inches in length for every four-week period thereafter to birth. This is equivalent to:

$$L = 2.5\ (T-3)+3, \text{ or, } L = 2.5T-4.5, \text{ or, } T = 0.4L+1.8,$$

where L is the total body-length in inches and T is the age in lunar months. In the metric system this becomes:

$$L' = 6.25T-11.25, \text{ or, } T = 0.16L'+1.8,$$

where L' is the total body-length in centimeters.

Roberts ('06) and Tuttle ('08) also have assumed a simple rectilinear relationship between age and body-length for the *latter* part of the fetal period, but their opinions seem to be based on "Hasse's rule."

A second class of expressions includes those that attempt to fit the fetal growth curve by splitting it into segments and devising a special formula for each segment. The first of these is the well known "Hasse's rule" (Hasse '77) by which the prenatal period is divided at five lunar months or 25 cm total body-length. The lower or earlier segment is represented by the expression:

$$T = \sqrt{L}, \text{ or, } L = T^2.$$

The upper or latter segment is represented by a straight line:

$$T = 0.2L, \text{ or, } L = 5T.$$

In these expressions T is the age in lunar months and L the total body-length in centimeters.

Another set of formulae of the phased type has been recently proposed by Arey ('23, '25), who employs rectilinear expressions phased at 10 cm crown-heel length and three lunar months. His published expressions are:

Standing height (cm.) $\times 0.2 =$ age (months)
Sitting height (cm.) $\times 0.3 =$ age (months)
(For embryos less than 10 cm. add one month.)
Age (months) $\div 0.2 =$ standing height (cm.)
Age (months) $\div 0.3 =$ sitting height (cm.)
(For embryos of first three months, subtract 4 cm.)

The first two, when reduced to the common form employed here, are:

$$T=0.2CH+1=0.3CR+1.$$

(For embryos less than 10 cm in length.)

$$T=0.2CH=0.3CR.$$

(For embryos of 10 cm and over in length.)
The literal analytical translations for the *latter* two statements (for embryos of the first three months) are:

$$CH=\frac{T}{0.2}-4, \text{ and, } CR=\frac{T}{0.3}-4.$$

The simplification of these forms to a more direct equivalent statement becomes:

$$CH=5T-4, \text{ and, } CR=3.33 \cdots T-4.$$

The analytic expressions of the author's published statement of the relationships for three lunar months and thereafter are:

$$CH=5T, \text{ and, } CR=3.33 \cdots T.$$

In these expressions CH is the crown-heel length in centimeters and CR the crown-rump length in centimeters.

The curvilinear formulae are more numerous. The first part of Hasse's rule really belongs in this class since it postulates that during the first half of pregnancy the square root of the body-length is equal to the age in lunar months. This relationship was restated, apparently independently, by Delabost in 1878. This author thought the rule could be applied for the first six months of prenatal life.

Henry and Bastien ('04) developed two rather complicated expressions for this relationship. The first, for age and length in the first three months of gestation, is:

$$2L^2-L(135-18T)+80T^2=0,$$

where L is the total body-length in centimeters and T is the age in solar months from conception. This, when put in the general form used in this discussion, becomes:

$$L=(33.75-4.5T)-0.25\sqrt{1,8225-4,860T-316T^2}.$$

The second, for the age-length relationship from three months gestation to birth, is:

$$608T^2-80TL+L^2+4,800T-110L+3,000=0,$$

where L is the total body-length in centimeters and T is the time in years from birth. This expression, when converted to the general form used in this account, is:

$$L=(40T+55)-0.5\sqrt{3,968T^2-1,600T+100},$$

or, $$T=(0.0658L-3.9474)+0.0008\sqrt{3,968L^2-500,480L+15,744,000}.$$

Scammon ('21), in the course of a study of the growth of premature infants, used the formula:

$$L=8.9(T-1)-0.27(T-1)^2-6.5,$$

or, $$L=9.44T-0.27T^2-15.67,$$

or, $$T=17.48-1.85\sqrt{72.19-1.08L},$$

where L is the total body-length in centimeters and T is the age in fetal or lunar months. This formula is an approximation for the body-length in the fetal period and early infancy in terms of cohabitation age. It is based upon the data of Mall ('10) and upon a large number of observations on the growth of infants in the first six months of postnatal life.

In 1923 the present writers published a series of empirical formulae for the relation of age to body-length from three fetal months to birth. The method of obtaining these expressions is described in Part I of this paper. In our original publication we presented the following expressions:

$$T=2.3+\frac{2.5L}{28}+\frac{L^2}{784}=\left(\frac{L}{28}+1.25\right)^2+0.74$$

$$L=28\sqrt{T-0.74}-35,$$

where T is the age in lunar months (of 28 days) computed from the first day of the last menstruation and L is the total or crown-heel length in centimeters. Since Mall's data indicate that the "cohabitation age" is ten days less, on the average, than the "menstrual age" as defined, the above formulae, when time is measured in "cohabitation age," become:

$$T=1.94+\frac{2.5L}{28}+\frac{L^2}{784}=\left(\frac{L}{28}+1.25\right)^2+0.38.$$

We also developed simpler but less precise expressions for ready use, viz.:

$$T=\left(\frac{L}{30}+1.49\right)^2$$

$$L=30\sqrt{T}-44.7.$$

In these T is "menstrual age" and L is body-length. In a more recent publication (Scammon and Calkins, '24) we have suggested another similar expression for determining menstrual age from length:

$$T=2.134+0.1L+0.0011L^2.$$

This does not fit the observed values quite as precisely as our original one, but it has an advantage for certain types of work since it holds good for the greater part of the third prenatal month as well as for the fetal period proper.

In this study we have made use of our formula of 1923,

$$T=2.3+\frac{2.5L}{28}+\frac{L^2}{784},$$

for computing the approximate menstrual age of the material. Since the great majority of the external dimensions of the body bear a rectilinear relationship to the total body-length (CH) we may approximate their growth with respect to time by substitution in the above formula. The crown-rump (CR) length of the body may be taken as an example to illustrate this process.

$$CR=0.66\ CH+0.5\ \text{(cm)},\ CH=\frac{CR-0.5}{0.66},$$

and $$T=2.3+\frac{2.5\ CH}{28}+\frac{(CH)^2}{784}.$$

Therefore, $$T=2.3+\frac{2.5\frac{CR-0.5}{0.66}}{28}+\frac{\left(\frac{CR-0.5}{0.66}\right)^2}{784}$$

$$=2.3+\frac{3.79\ CR-1.894}{28}+\frac{(CR)^2-1.0\ CR+0.25}{342}$$

$$=2.23+\frac{CR}{7.56}+\left(\frac{CR}{18.49}\right)^2.$$

In practice it is, of course, much simpler to use the computed total body-length at any desired age and to compute the calculated value of any dimension in question. The various tables and graphs that deal with the relations of the several dimensions of the body to age in the fetal period have been computed by this method.

In general these computations indicate that all of the dimensions of the body (with the exception of the few affected by postural artifacts and which are phased in connection with body-length) show a rapid increase in early fetal life and a steady decline in growth rate thereafter. This decline is more pronounced for the dimensions of the head and neck than for those of the trunk, and is greater for the dimensions of the trunk than for those of the pelvis and the extremities.

The validity of all these measures of dimensions with respect to time, therefore, rests on the reliability, first, of the formulae for the relation of the dimension of the part to the total length of the body and, second, on the reliability of the formula used for approximating the relation of total body-length to time or age. Measures of the reliability of the expressions for the first relationship are given in the various test tables of this study. The reliability of the expression for the total length-age relation is indicated in table 9 of Part I of this monograph. The deviations of the calculated values from the observed values of Mall, to which the fit was made, are quite small. Future research may produce more accurate data for this relationship. In that case the conclusions given here may require some modification.

IV. Variability of the External Dimensions of the Body in the Fetal Period

Our consideration of the variabilities of the external dimensions of the body has been limited to their pictorial representation in field graphs, to a measure of the deviations of *all* of the observations of certain selected dimensions from their regression lines, and to statements regarding the maximum and minimum values for each 5 cm interval of body-length. The last are of comparatively little significance.

The reasons for omitting a more detailed presentation of the variability of the material by 5 cm intervals of body-length or by lunar months are several. The data under consideration do not represent measurements of static objects but of growing ones. They therefore form progressions with respect to age or time. They may also be arranged in progressions with respect to one another, for example, to the total body-length, as has been done in this study. If the observations of the dimensions are so arranged, the progression thus formed may be split into any number of intervals or segments, and the means and deviations of the individual cases from these means may be ascertained. The resulting figures will represent the variation in the data as set down on paper, but they will not be measures of the "true" or "gratuitous" variation of the material, for they are the sums of two main factors; first, the variation in the size of the dimensions due to their relation to body-length; and, second, the "true" variability. While the progression factor in the measures of variability may be diminished by reducing the size of the segment or interval of the progression, this (in any limited series of cases) also reduces the number of observations in the segment, and the measure becomes increasingly unreliable. Obviously, if all the specimens in a given interval or panel were of the same body-length, the variability could be easily determined. But, in fact, in appreciable intervals of body-length the observations are irregularly scattered from the upper to the lower limits of the panel. Therefore, the figures for variability given by this method may represent one's fortune in obtaining material falling in any given panel as much or more than the "true" variability of this material.

If the variation is computed for intervals of time rather than intervals of body-length, the unreliability of the measure is increased, first, because computations of age are frequently based on either body-length or upon criteria that are still less certain, and, second, because of the differences in the amount of growth occurring in equal time intervals in the fetal period.

These strictures hold true for the measurement of the variability of ratios as well as of absolute dimensions, if these ratios show a definite trend or progression.

In practice, it is possible to correct the measures of the variation for the progression factor, if certain assumptions are made regarding the distribution. The correction, for example, becomes very simple on the assumptions that the distribution of observations is uniform with respect to the axis of the independent variable, that it is normal at any point on the trend, and that the trend may be represented by a straight line within the panel or interval. But these assumptions, with the exception of the last one, do not hold true for our material, and it is difficult to form an estimate of the factors involved in the approximation.

We think a better attack on the problem is by the consideration of variability of the whole of the material of the progression about a defined central tendency. The logical basis is more definite than that underlying the concept of variability in panels or segments of the progression, for this concept is obscured by the difficulty in defining "the true or theoretical trend" in the several segments. If one accepts the view that a "trend" cannot exist irrespective of some set of data (which eanms that it is subject to arbitrariness in definition and is influenced by the variability of the material), a theoretical, or "true," trend may be defined with respect to these data. The variability of the individual observations about it is, therefore, the "true" variability of the material, this variability also being subject to definition. The practical advantage of this approach lies in the fact that the approximations are included in the definitions, and there is no need of making further assumptions that may be contrary to fact.

We have adopted the regression line as the "true trend," and defined the variability as the root mean square deviation of the individual observations about this line. As samples we chose from the 70 dimensions under consideration the 6 showing the most scatter on field graphs and the 6 showing the least, and calculated their variability as defined above. The computations were subject to approximations justified by the experimental error involved in taking the measurements. The absolute values of the results were all small, ranging from 0.31 to 1.14 cm. These are shown in detail in tables 166 and 167 of this monograph. A calculation of this measure for *all* the dimensions studied would hardly justify the labor involved. In the first place the magnitudes of the various dimensions are so different that no precise measure of their relative variability can be calculated. And, second, a simple interpretation of the results is impossible because of the complications introduced by the artifacts that affect the upper parts of the progressions of the more variable measurements.

V. Sex Differences in External Bodily Dimensions in the Fetal Period

No detailed study was made of possible sex differences in these data. However, the observations were all originally grouped according to sex, and the sex distinction was kept in all of the field graphs made in the course of the investigation. These are shown in the concluding section of this monograph. The inspection of these graphs gives no indication of any constant sex difference in the various dimensions that have been measured. This conclusion is in agreement with that of Schultz ('22, '23, '26) and of Reicher ('23), and opposed to that of Hamy ('80).

However, it should be made clear that this opinion is based upon inspection only, and that a real statistical test of this conclusion in the form of the determination of the probable errors of the differences of the means for males and females is quite impossible because of the nature of the distribution of the material. Furthermore, the classification of the material is based upon the total body-length or upon a convention for age as determined from the body-length.

If thoroughly reliable histories were available for all specimens, so that the material could be studied in connection with age or time, it is possible that differences masked in a classification based on stature alone would appear. Sex differences in the *time of ossification* of certain parts of the skeleton in prenatal life have been noted (Adair and Scammon '21, and Pryor '22, '23), and the presence of these differences, with respect to time, in the various external bodily dimensions measured from skeletal landmarks is quite possible, although we have not been able to distinguish them.

PART X

GENERAL SUMMARY

I. Outline of Material and Methods

A quantitative study has been made of 71 external dimensions of the human body in the fetal period (from approximately three fetal or lunar months to birth). Each dimension has been measured (on the average) on over 300 specimens, ranging from approximately 2 cm to 55 cm in total or crown-heel length. This represents some 25,000 quantitative observations. Approximately 10,000 additional measurements were made in connection with the study of effects of artifacts on the material.

Only Caucasian material was used. The racial origins were quite varied but were largely northern European.

It was found that the external dimensions of the body, in material of the type used in this and similar studies, are considerably modified by artifacts. Of these, the chief are: first, those produced by the effects of birth on the size and form of the head; second, those due to changes in the dimensions of the chest concomitant with partial or complete establishment of respiration; and, third, the effects of formalin preservation, and formalin injection and preservation on the material.

These artifacts have been measured and studied quantitatively; the first two by observations on living, newborn infants, and the last by repeated measurements of fresh and preserved specimens. Correction factors for most of these artifacts have been developed from these studies.

The reliability of measures of stature in the fetal period has been determined experimentally and statistically, and the crown-heel or total body-length has been found a more satisfactory measure than the crown-rump length or sitting-height.

The data have been represented graphically by field graphs and curves of central tendency for each dimension studied.

The observations on each dimension have been summarized in the form of tables for 5 cm intervals of crown-heel length. These include the mean crown-heel length, the mean crown-rump length, and the mean, minimum, and maximum measurements of the dimension under consideration.

The central tendency of each dimension, with respect to total body-length, has been expressed analytically by empirical formulae, the constants of which were determined by graphic methods, by the method of means or averages, and by the method of least squares. Tests of the results of these various methods of curve fitting are given in tables 164 and 165.

These analytic expressions have been determined from the means of each dimension for 5 cm intervals of total or crown-heel length. The precision of this method, as compared to that obtained by use of the regression line, has been tested by use of a "deviation ratio." The differences, which are not great, are shown and discussed in Part I of this monograph.

The relations between the magnitude of the various external bodily dimensions and age or time in the fetal period have been represented by curves and figures based upon an analytic convention expressing the relation of total body-length to fetal age. This expression has been developed from the observations of Mall ('10) after a careful comparison of over 20 sets of data on this subject. The accuracy of this formula and its comparison with previous length-age formulae are discussed in Parts I and IX of this monograph.

Secondary computations have been made for each dimension. They show the calculated values at each 5 cm interval of body-length; the amount of absolute and relative gain in each 5 cm interval; the differences between computed and observed values; the calculated value at each 5 cm interval expressed as a percentage of the computed newborn value; the relative size (with respect to body-length) at each 5 cm interval of body-length and at each lunar month; the calculated value at each lunar month; and the amount of absolute and relative gain in each fetal or lunar month.

A series of approximate values have been computed from the calculated figures for a series of some 50 anthropometric indices of various parts of the body. These are given and discussed in the summaries of the subsections in Parts III to VIII, inclusive, of this monograph.

An expression, termed the "length-interval ratio," has been developed for measuring the relative amount of growth with respect to body-length, and applied to the study of the "law of developmental direction" in the fetal period. This is discussed in Part IX of this monograph.

A series of drawings representing the "predicted" external form of the fetus at each 5 cm interval of body-length and each fetal month, have been drawn up from the preceding computations and form figures 70, 71, 72, and 73 of this publication.

II. Analysis of the Literature

The available published quantitative data on the general growth of the external dimensions of the human fetus and their sizes in the newborn have been collated and abstracted. This summary (which forms Part II of the present study) gives an index to the published material of some 90 observers. It is estimated that this material includes, in detail or in summary, over 160,000 observations upon more than 100 external dimensions of the body.

The available published material on fetal growth, with respect to body-length, of the external dimensions of the body that are considered in this study has been tabulated and is summarized in tables 168 to 180, inclusive, of this publication. One hundred and seventy-five sets of data of this kind were located. They deal with 41 external bodily dimensions and include over 16,000 observations.

The results of previous observers, when given in a form comparable with that used in this study, have been shown graphically in a series of 145 curves included in Parts III to VIII, inclusive, of this publication.

A large number (we think all) of the empirical formulae for the relation between the total body-length and age or time in the fetal period proper have been collated and analyzed (Part IX, Section III).

III. General Conclusions

The increases in the various external dimensions of the body in the fetal period bear a rectilinear relationship to body-length. The relation of these dimensions may therefore be expressed as:

$$D = aL + b,$$

where D is the dimension, a is a constant in the form of a decimal fraction, L is the total or crown-heel length of the body, and b is a second constant, that may be positive, negative, or zero. (The only exceptions to this statement are certain measurements along the ventral median line of the body that seem to be affected by fetal posture.)

This relationship indicates that the increase of the various external dimensions is constantly directly proportional to the increase in body-length in the fetal period.

The formulae for the dimensions of the head, neck, and upper portion of the chest and also of major dimensions involving the head are characterized by positive b constants. Therefore, these dimensions are relatively larger in the early part of the fetal period than at its close, and have made a greater amount of growth with respect to body-length in the embryonic period than they do in equal later intervals of body-length.

Some dimensions of the upper part of the trunk have zero or approximately zero b constants. These dimensions show no change in relative size in the fetal period.

The formulae for the dimensions of the lower part of the trunk, the pelvis, and the upper and lower extremities are characterized by negative b constants. These dimensions have undergone less increase in size in the embryonic period than they do in any corresponding interval of increase in crown-heel length in the fetal period. They show an increase in relative size in the fetal period.

These relationships illustrate the existence by regions of the sequence known as the "law of developmental direction."

Further study of the various formulae with the use of the "length-interval ratio" indicates that this sequence holds true not only for the several regions of the body but also for the dimensions of each region of the body.

The growth in total body-length with respect to time or age in the fetal period, as defined by the convention adopted for this study, is represented by the parabola:

$$L = 28\sqrt{T-0.74} - 35, \text{ or, } T = 2.3 + \frac{2.5L}{28} + \frac{L^2}{784},$$

where L is the total or crown-heel length of the body in centimeters and T is the age in fetal or lunar months. This formula does not hold good below three lunar months.

According to this expression the body-length shows a rapid increase in the beginning fetal period and a steady decline in growth rate thereafter.

The various external dimensions of the body, when related to age or time by substitution for body-length in the above formula, follow the same general course of growth as the total body-length.

When computed with respect to age, the dimensions of the head, neck, and upper part of the trunk show a more marked decline in growth rate in the fetal period than do those of the lower part of the trunk, the pelvis, and the extremities.

No detailed analysis of variability in fetal measurements was made in this study. However, this variability is shown graphically in the field graphs and a measure of the deviations of the individual observations about the line of central tendency has been computed for a representative sample of the dimensions and included in tables 166 and 167.

No sex differences in the various external dimensions of the body were demonstrated in this study.

IV. Digest of Findings Regarding the Special Regions of the Body

1. The Major External Dimensions

The growth of the major external dimensions (exclusive of the total or crown-heel length) was studied on the basis of measurements of crown-rump length (sitting-height), spine length, distance from crown to umbilicus, and distance from crown to sternal notch.

The first three of these dimensions appear as straight lines when plotted against the total or crown-heel body-length. The distance from crown to sternal notch is better represented by two straight lines phased at 30 cm crown-heel length.

Empirical formulae for these relationships have been developed by graphic methods, the method of averages, and the method of least squares. All the formulae thus developed may be represented by the general expression:

$$MD = aL + b,$$

where MD is any one of the major dimensions measured, L is the total or crown-heel body-length, a is a positive constant less than unity, and b is a second and positive constant.

The presence of positive b constants indicates that all the dimensions of the group undergo a reduction in relative size in the fetal period. The crown-rump length or sitting-height forms about three-fifths of the body-length at three fetal months and about two-thirds at birth. The distance from crown to umbilicus forms about three-fourths of the body-length at three fetal months and but a little over one-half at birth. The distance from crown to sternal notch forms somewhat more than one-third of the body-length at three fetal months and somewhat over one-fourth at birth. The spine length also shows a slight relative decrease in this period.

The total or crown-heel body-length increases a little over sevenfold between three fetal months and birth; the increments of the major dimensions in this period range from a little less than sevenfold to somewhat less than sixfold.

The bi-phased character of the expression for the relation of the distance from crown to umbilicus to the total body-length is probably not indicative of a change in the course of growth of this dimension but represents the effect of postural and other artifacts upon these data.

2. The Head and Neck

The growth of the head and neck in the fetal period has been studied by means of measurements of 22 external dimensions of this region. Of these 14 were linear and 8 were circumferential or perimetric dimensions.

All of these dimensions show a rectilinear distribution with respect to the total or crown-heel length.

Empirical formulae for these distributions have been developed by graphic methods, the method of averages, and the method of least squares. Of the 66 formulae thus developed (1 for each of the 22 dimensions by each of the 3 methods) 63 are characterized by positive secondary or b constants. The three exceptions are the formulae for the bi-malar diameter or distance as determined by the method of averages and by the method of least squares, and the expression for the orbito-auricular distance as determined by graphic methods. With the preceding exceptions the formulae for the relationship of external dimensions of the head to the total body-length are:

$$HD = aL + b,$$

where HD is any external head dimension, L is the total body-length, a is a positive constant less than unity, and b is a second and positive constant.

The above findings indicate that, as a whole, the amount of growth of the external dimensions of the head is directly proportional to that of the crown-heel body-length in the fetal period but that these dimensions become relatively smaller (although absolutely greater) in this period.

The total head and face height forms nearly one-third of the total body-length at three fetal months, about one-quarter at six months, and a little less than one-quarter at birth.

The height of the cranial part of the head (from external auditory meatus to vertex) forms a little more than one-fifth of the total body-length at three fetal months and somewhat less than one-fifth at birth.

The computed head moduli all undergo a decrease in relative size in the fetal period.

All of our computed values indicate a slight increase in the cephalic index in the fetal period, but the individual variations in this index make us doubt if this finding is significant.

All of our computed indices show that the cranium is becoming longer and broader in proportion to its height in the fetal period.

The facial portion of the head grows more relatively in height and breadth and (presumably) in antero-posterior diameter than does the cranial portion in the fetal period.

The face becomes relatively a little broader in the fetal period, as indicated by the relationship of the computed bi-malar diameter to the nasion-menton diameter.

The growth of the face in the antero-posterior axis (in as far as it is indicated by measurement of the orbito-auricular distance), is somewhat greater relatively than the growth in the cranio-caudal axis (face height).

The computed indices for the relation of face breadth to antero-posterior facial diameter (as represented by the orbito-auricular distance) vary slightly with the type of fitting employed in computation. The relation, as determined by graphic methods, seems to remain quite constant for the fetal period, while the ratios determined by the methods of averages and by least squares indicate that the breadth of the face increases somewhat less, relatively, than its antero-posterior diameter.

The various dimensions of the head and neck increase between fivefold and about sevenfold between the third fetal month and birth.

3. The Trunk

The growth of the trunk, exclusive of the pelvis, was studied by means of measurements of 22 external dimensions, 5 of which were circumferential and 17 were linear. Of the 17 linear dimensions, 6 lay in the median plane of the body on its anterior surface and in the cranio-caudal axis, 7 were in the transverse axis, and 4 were in the antero-posterior axis.

When plotted against the total or crown-heel body-length, 17 of these dimensions appeared in a rectilinear relationship, 4 could be fairly represented by straight lines phased near the middle of the progression, and 1 was represented by a straight line for the first part of the progresssion and a shallow curve for the latter part.

Empirical formulae for the 17 dimensions bearing rectilinear relationships to the total body-length were developed by graphic methods, by the method of averages, and by the method of least squares. For the 51 formulae thus developed, 33 of the secondary or *b* constants were negative, 10 were positive, and 8 were zero. In 9 instances the sign of the secondary constant was changed by the method of calculation employed, but in most of these instances the magnitudes of these constants were small.

Nine of these simple linear formulae express the relationships of dimensions of the thorax that also involve proximal portions of the shoulder girdle. These expressions (with one exception, the formula for the bi-acromial diameter as determined by graphic methods) all have negative *b* constants, which is characteristic for the relationships of the dimensions of the extremities to body-length.

Twenty-one of the simple linear formulae are for dimensions of the thorax only. In 7 of these the *b* constant is zero, in 8 it is positive, and in 6 it is negative.

Eighteen of the rectilinear formulae are for dimensions of the abdominal region (dimensions at the level of the tenth rib are included in this category). Two of these formulae have small positive *b* constants (circumference at the tenth rib as determined by the method of averages and by the method of least squares), and the remaining 16 were characterized by negative constants.

In general, the findings recorded above indicate that the formulae for dimensions under consideration are usually characterized by positive or zero *b* constants in the upper part of the trunk proper, while the formulae for the abdominal dimensions and for those dimensions involving parts of the shoulder girdle have negative *b* constants. The former decrease and the latter increase in relative size during the fetal period.

The 5 dimensions that did not appear as single straight lines, when plotted against the total body-length, were all cranio-caudal measurements in the median line of the ventral or anterior surface of the body. As they were point-to-point measurements, they involved growth changes in the antero-posterior as well as the cranio-caudal planes of the body. Evidence from our own material, as well as certain observations made by other investigators, leads us to believe that these dimensions are greatly affected by posture; and we are of the opinion that the bi-phased character of their relation to the total body-length is due to artifacts.

The various external dimensions of the trunk increase between sevenfold and ninefold in the fetal period (three fetal months to birth).

The trunk becomes more slender, relative to body-length, in the latter part of the fetal period.

The thoracic indices at the level of the nipples, the level of the xiphi-sternal junction, and the level of the tenth rib have been computed from the formulae for the transverse and antero-posterior diameters of the chest as determined by graphic methods, and the methods of averages and least squares. The values obtained show very little change in this index in the fetal period.

The length of the thorax (as indicated by the distance from the sternal notch to the xiphi-sternal junction) is increasing relatively more rapidly in the fetal period than either the breadth or depth of the chest.

Indices computed by dividing the calculated transverse and the antero-posterior diameters of the chest by the corresponding calculated diameters at the level of the tenth rib show that the lower part of the thorax grows relatively, as well as absolutely, more rapidly than the upper portion.

In the fetal period the girth of the abdomen (at the level of the umbilicus) increases more rapidly (both relatively and absolutely) than the girth of the thorax (at the level of the nipples).

4. The Pelvis

The growth of the pelvis has been studied by means of measurements of 6 external dimensions. Of these 4 were measurements in the transverse plane, 1 a measurement in the antero-posterior plane, and 1 in the vertical plane of the body.

All of the external dimensions of the pelvic region appear to be straight lines when plotted against the total or crown-heel body-length.

Empirical formulae for these straight lines were developed by graphic methods, the method of averages, and the method of least squares. Of the 18 formulae thus developed (3 for each of the 6 dimensions), 17 are characterized by negative secondary or b constants. The one exception is the formula for the bi-tuberous distance, as developed by graphic methods, which has a zero b constant. With the preceding exception, the relations of the various external pelvic dimensions to the total body-length may be represented by the general formula:

$$PD = aL + b,$$

where PD is any external pelvic dimension, L is the total body-length, a is a positive constant less than unity, and b is a second negative constant.

As indicated by the above formulae, the external dimensions of the pelvis undergo an increase in relative as well as absolute size in the fetal period.

Indices developed from empirical formulae show that the breadth of the pelvic girdle (as represented by the intercristal or by the intertrochanteric diameter) increases more rapidly, relative to body-length, in the fetal period than does the breadth of the shoulder girdle.

The various external dimensions of the pelvis increase between sevenfold and tenfold in the fetal period. The greatest relative increase is made by the pelvic height and the least by the bi-tuberous distance.

Indices computed from empirical formulae show that the pelvis is growing relatively more rapidly in height than in breadth in the fetal period.

The antero-posterior diameter of the pelvis seems to increase more slowly than the transverse diameters of the pelvis in the fetal period.

Indices computed from empirical formulae show that in the fetal period the intertrochanteric diameter makes the greatest relative, as well as absolute, increase of the three major transverse diameters of the pelvis. The relative growths of the intercristal and the interspinous diameters are much the same in this period, although the latter is a little greater.

5. The Upper Extremity

The growth of the upper extremity has been studied by the systematic measurement of 8 external dimensions of which 5 were linear and 3 were circumferential.

All of these dimensions appear as straight lines when plotted against the total or crown-heel body-length.

Empirical formulae for these relationships have been developed by graphic methods, the method of averages, and the method of least squares. Of the 24 formulae thus developed (3 for each of the 8 dimensions), 22 are characterized by negative secondary or b constants. Two, the expressions for the length of the arm (from acromion to elbow) as determined by the method of averages and by the method of least squares, have very small positive secondary or b constants. With the preceding exceptions, the relationships of the various external dimensions of the upper extremity may be expressed by the general formula:

$$DUE = aL + b,$$

where DUE is the external dimension, L is the total body-length, a is a positive constant less than unity, and b is a second and negative constant.

The presence of negative secondary constants in the great majority of these formulae indicates that the external dimensions of the upper extremity are increasing in relative as well as in absolute size in the fetal period.

The length of the upper extremity as a whole approximates one-third of the total body-length at three fetal months and about two-fifths at birth. The length of the upper extremity is between one-half and two-fifths of the sitting-height at the beginning of the fetal period and about three-fifths at birth.

Between three fetal months and birth the length of the upper extremity increases about eightfold, the arm length about ninefold, the forearm length between sevenfold and eightfold, the hand length about eightfold, and the middle-finger length about tenfold. In the same period the arm circumference increases about fifteenfold, the forearm circumference about fourteenfold, and the wrist circumference about thirteenfold.

The computed brachial index (forearm length divided by arm length and multiplied by 100) undergoes a constant reduction in the fetal period.

The computed indices show a constant increase in hand length with respect to forearm length in the fetal period.

The computed indices show a constant increase in middle-finger length with respect to hand length in the fetal period.

When the girths of the arm and forearm are compared, by the computed arm-proportion index, it is found that the latter is making the more rapid relative growth in the fetal period.

6. The Lower Extremity

The growth of the lower extremity was studied by measurements of 8 external dimensions, 6 of which were linear and 2 were circumferential.

All of the external dimensions of the lower extremity approximated straight lines when plotted against the total or crown-heel body-length.

Empirical formulae for expressing the relations between the total body-length and the various external dimensions of the lower extremity were developed by graphic methods, the method of averages, and the method of least squares. All of these (24) formulae proved to be of the general type:

$$DLE = aL + b,$$

where DLE is the external dimension of the lower extremity, L is the total or crown-heel body-length, a is a positive constant less than unity, and b is a second and negative constant.

The skelic index (ratio of lower extremity length to the crown-rump length) undergoes a marked increase in the fetal period.

The first intermembral index (ratio of upper extremity length to lower extremity length) undergoes a marked reduction during the course of the fetal period.

The second intermembral index (ratio of combined length of the arm and forearm to the combined lengths of the leg and thigh) is reduced more in the fetal period than the first intermembral index.

The upper and lower extremities are of about equal length at 7 cm crown-heel length (or late in the third fetal month). Before this stage the length of the upper extremity exceeds that of the lower; after this stage this relation is reversed. At no time in the fetal period proper does the combined length of the arm and forearm equal the combined length of the leg and thigh.

The computed tibio-femoral index shows that the length of the leg increases more, relative to body-length, than the length of the thigh in the fetal period.

Computed indices for the ratio of foot length to leg length show that the former measurement is growing relatively more than the latter in the fetal period.

The computed leg-proportion index (circumference of calf divided by the circumference of the thigh with the result multiplied by 100) undergoes a marked increase in the fetal period, showing that the calf girth increases relatively much more than the thigh girth in the fetal period.

PART XI

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TABLES, GRAPHS, AND FIGURES

PART XII

TABLES OF EMPIRICAL FORMULAE AND THEIR RESIDUALS

TABLE 163

Constants of Empirical Formulae (as determined by Various Methods) for Computing the Probable Size of the External Dimensions of the Body from the Crown-heel Length in the Fetal Period

Dimension	Number of range-averages used in (2) and (3)	Graphic method (1)		Method of averages (2)		Method of least squares (3)	
		a	b	a	b	a	b
General							
Sitting height (crown-rump length)	11	0.66	+ 5.0	0.669	+ 4.81	0.671	+ 4.14
Spine length	7	0.43	+ 4.0	0.426	+ 4.22	0.429	+ 3.47
Crown to umbilicus	8	0.52	+ 5.5	0.517	+ 6.74	0.520	+ 6.06
Crown to suprasternal notch	5	0.3	+ 4.0	0.297	+ 5.05	0.289	+ 6.34
	5	0.24	+ 22.0	0.233	+ 24.99	0.236	+ 23.70
Head and Neck							
Occipito-frontal circumference	7	0.675	+ 13.0	0.674	+ 13.33	0.675	+ 13.21
Occipito-frontal diameter	7	0.235	+ 4.0	0.232	+ 4.72	0.232	+ 4.70
Suboccipito-bregmatic circumference	7	0.625	+ 16.0	0.628	+ 16.28	0.622	+ 17.85
Suboccipito-bregmatic diameter	7	0.20	+ 6.0	0.196	+ 7.40	0.195	+ 7.54
Suboccipito-frontal circumference	7	0.65	+ 15.0	0.641	+ 18.90	0.641	+ 19.07
Suboccipito-frontal diameter	7	0.215	+ 7.00	0.211	+ 7.86	0.211	+ 7.81
Occipito-mental circumference	10	0.63	+ 9.00	0.630	+ 9.73	0.631	+ 9.61
Occipito-mental diameter	7	0.235	+ 2.0	0.238	+ 1.64	0.236	+ 2.24
Large circumference (menton-lambda)	7	0.72	+ 10.0	0.686	+ 14.51	0.662	+ 20.83
Bi-parietal diameter	7	0.19	+ 2.0	0.182	+ 3.57	0.184	+ 3.08
Auriculo-vertex-auricular circumference	8	0.4675	+ 11.0	0.4365	+ 15.91	0.4234	+ 19.52
Vertical auriculo-vertex distance	10	0.175	+ 3.50	0.159	+ 6.51	0.157	+ 7.10
Suboccipito-vertex-nasion circumference	10	0.465	+ 15.00	0.445	+ 18.45	0.439	+ 20.03
Menton-bregma diameter	6	0.23	+ 4.5	0.216	+ 6.51	0.202	+ 9.84
Bi-malar distance (or diameter)	10	0.1375	+ 0.25	0.1435	− 1.63	0.1435	− 1.63
Bi-auricular diameter	7	0.16	+ 2.00	0.147	+ 4.65	0.143	+ 5.70
Auriculo-vertex diameter	10	0.1825	+ 4.50	0.1676	+ 7.11	0.1662	+ 7.54
Nasion-menton distance	9	0.105	+ 0.50	0.101	+ 1.08	0.101	+ 0.99
Vertical head height	10	0.2275	+ 5.00	0.220	+ 6.49	0.217	+ 7.17
Orbito-auricular distance	9	0.0775	± 0.00	0.075	+ 0.75	0.076	+ 0.58
Orbito-auriculo-suboccipital diameter	10	0.1725	+ 2.00	0.1698	+ 2.53	0.1699	+ 2.51
Circumference of neck	7	0.33	+ 2.00	0.3162	+ 3.71	0.307	+ 6.09
Trunk							
Bi-acromial diameter	10	0.225	± 0.00	0.233	− 1.52	0.236	− 2.50
Nipple to nipple distance	8	0.125	± 0.00	0.127	− 0.36	0.131	− 1.51
Bi-deltoid circumference	7	0.6525	− 2.50	0.6567	− 3.98	0.6547	− 3.44
Bi-deltoid diameter	8	0.27	− 2.50	0.272	− 2.77	0.276	− 3.90
Circumference at nipples	8	0.60	± 0.00	0.594	+ 1.82	0.595	+ 1.37
Transverse diameter at nipples	8	0.2025	± 0.00	0.2060	− 0.39	0.2030	+ 0.29
Antero-posterior diameter at nipples	8	0.175	± 0.00	0.171	+ 0.19	0.172	± 0.00
Circumference at xiphi-sternal junction	8	0.62	− 1.00	0.5855	+ 6.73	0.582	+ 7.64
Transverse diameter at xiphi-sternal junc.	8	0.205	± 0.00	0.206	− 0.68	0.207	− 0.86
Antero-posterior diam. at xiphi-sternal junc.	8	0.18	± 0.00	0.178	+ 0.35	0.179	+ 0.09
Circumference at tenth rib	8	0.64	− 4.00	0.597	+ 2.45	0.584	+ 5.96
Transverse diameter at tenth rib	8	0.2075	− 1.00	0.2161	− 2.69	0.2183	− 3.31

TABLE 163—*Concluded*

Constants of Empirical Formulae (as determined by Various Methods) for Computing the Probable Size of the External Dimensions of the Body from the Crown-heel Length in the Fetal Period

Dimension	Number of range-averages used in (2) and (3)	Graphic method (1)		Method of averages (2)		Method of least squares (3)	
		a	b	a	b	a	b
Trunk—*concluded*							
Antero-posterior diameter at tenth rib	8	0.1825	− 1.00	0.1856	− 1.66	0.1868	− 1.99
Circumference at umbilicus	7	0.5525	− 5.50	0.5476	− 5.52	0.5418	− 4.02
Transverse diameter at umbilicus	8	0.19	− 2.00	0.201	− 3.90	0.205	− 4.94
Antero-posterior diameter at umbilicus	7	0.165	− 1.00	0.164	− 1.03	0.167	− 1.89
Sternal notch to pubis	5	0.4	$-2\sqrt{CH_{mm.}}+2mm.$	0.273	+ 2.61	0.279	+ 1.62
	5	0.28	+ 1.5	—	—	—	—
Sternal notch to umbilicus	4	0.22	+ 1.5	0.212	+ 3.01	0.215	+ 2.58
	3	0.27	− 11.0	0.276	− 11.70	0.263	− 7.23
Sternal notch to xiphi-sternal junction	10	0.11	− 1.5	0.113	− 2.20	0.111	− 1.84
Xiphi-sternal junction to pubis	4	0.19	+ 1.5	0.172	+ 3.62	0.179	+ 2.58
	4	0.26	− 16.00	0.281	− 23.15	0.276	− 21.23
Xiphi-sternal junction to umbilicus	4	0.125	+ 1.75	0.123	+ 2.45	0.129	+ 1.66
	4	0.18	− 12.00	0.190	− 15.79	0.181	− 12.50
Umbilicus to pubis	4	0.072	− 0.5	0.058	+ 0.93	0.061	+ 0.52
	4	0.09	− 5.0	0.111	− 11.20	0.106	− 9.39
Pelvis							
Height of pelvis (crest of ilium to rump)	10	0.155	− 4.0	0.153	− 3.83	0.154	− 4.15
Interspinous diameter	8	0.145	− 2.50	0.147	− 2.96	0.148	− 3.20
Intercristal diameter	8	0.1625	− 2.50	0.1666	− 3.83	0.1659	− 3.65
Intertrochanteric diameter	8	0.1775	− 3.50	0.1863	− 5.64	0.1872	− 5.91
External conjugate diameter	7	0.115	− 1.00	0.112	− 0.84	0.109	− 0.11
Bi-tuberous distance	8	0.04	± 0.00	0.045	− 1.13	0.046	− 1.63
Extremities							
Length of upper extremity	10	0.40	− 4.00	0.399	− 3.40	0.398	− 3.35
Length of arm (acromion to elbow)	10	0.155	− 0.50	0.152	+ 0.27	0.152	+ 0.40
Length of forearm	10	0.13	− 1.50	0.126	− 0.50	0.126	− 0.58
Length of hand	10	0.12	− 3.00	0.123	− 3.74	0.121	− 3.35
Length of middle finger	10	0.075	− 3.00	0.074	− 2.76	0.074	− 2.61
Circumference of arm	8	0.195	− 8.00	0.193	− 7.11	0.194	− 7.49
Circumference of forearm	8	0.195	− 7.50	0.195	− 7.30	0.197	− 7.61
Circumference of wrist	10	0.165	− 10.00	0.163	− 9.78	0.163	− 9.59
Length of lower extremity	10	0.43	− 7.00	0.429	− 7.22	0.433	− 8.30
Length of thigh (post.-sup. iliac spine to knee)	10	0.25	− 2.00	0.252	− 2.30	0.254	− 2.84
Length of thigh (trochanter to knee)	10	0.19	− 2.00	0.189	− 1.68	0.189	− 1.65
Length of leg (knee to lateral malleolus)	10	0.2	− 4.5	0.196	− 3.34	0.197	− 3.51
Height of foot	10	0.04	− 1.5	0.044	− 2.44	0.045	− 2.68
Length of foot	10	0.16	− 6.5	0.159	− 6.11	0.157	− 5.53
Circumference of thigh	7	0.31	− 13.00	0.312	− 13.76	0.314	− 14.26
Circumference of calf	8	0.22	− 10.50	0.222	− 11.00	0.219	− 10.28

TABLE 164

Average Deviations of the Calculated Values of the Various External Dimensions of the Body (as determined from the Formulae given in Table 163) from the Corresponding Observed Values for Five Centimeter Range Averages of Crown-heel Length in the Fetal Period

Dimension	Graphic method								Method of averages				Method of least squares			
	Without regard to sign				With regard to sign				Without regard to sign				Without regard to sign			
	Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted	
	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.
General																
Sitting height (crown-rump length)	3.21	1.55	2.75	1.43	−2.23	−1.03	−1.58	−0.79	2.95	1.85	2.87	1.87	2.97	1.91	2.88	1.91
Spine length	3.25	2.07	2.77	1.97	−1.61	−0.55	−0.79	−0.05	3.58	2.19	2.92	1.97	3.44	2.21	2.80	1.97
Crown to umbilicus	1.93	1.35	1.77	1.33	−5.70	−0.61	−0.45	−0.60	1.77	0.96	1.59	0.92	1.83	1.13	1.68	1.10
Crown to suprasternal notch	3.72	3.57	3.13	3.13	+3.22	+2.53	+2.76	+2.31	3.12	2.88	2.52	2.37	3.77	3.82	3.29	3.49
Head and Neck																
Occipito-frontal circumference	4.76	1.97	4.08	1.86	+3.22	+1.05	+2.27	+0.81	4.76	2.08	4.06	1.87	4.77	2.10	4.07	1.89
Occipito-frontal diameter	2.31	2.26	1.91	1.95	+1.97	+1.70	+1.59	+1.18	2.21	2.45	1.88	2.20	2.21	2.44	2.20	2.20
Suboccipito-bregmatic circumference	4.60	1.99	4.19	1.93	+1.86	+0.47	+0.79	±0.00	4.78	2.05	4.11	1.84	4.39	2.06	3.73	1.81
Suboccipito-bregmatic diameter	2.08	2.66	1.77	2.42	+1.22	+0.84	+0.72	+0.23	1.81	2.56	1.52	2.25	1.81	2.61	1.52	2.30
Suboccipito-frontal circumference	5.11	2.33	5.07	2.39	+1.84	+0.15	+0.67	−0.30	5.30	2.68	4.66	2.45	5.26	2.68	4.63	2.46
Suboccipito-frontal diameter	2.32	3.01	2.14	2.69	+1.83	+1.87	+1.26	+1.22	2.45	3.21	2.11	2.89	2.26	3.02	1.95	2.74
Occipito-mental circumference	3.88	2.42	4.11	2.62	−0.02	+0.10	−1.43	−0.20	3.87	2.59	4.00	2.73	3.85	2.56	3.35	2.71
Occipito-mental diameter	0.92	1.49	0.96	1.61	−0.08	−0.25	−0.23	−0.39	1.09	1.61	1.02	1.60	0.94	1.41	0.92	1.48
Large circumference (menton-lambda)	2.16	1.24	2.10	1.28	−0.12	−0.30	−0.30	+0.21	6.97	3.25	6.50	2.77	9.68	4.95	8.77	4.71
Bi-parietal diameter	2.29	3.18	1.92	2.83	+1.91	+2.02	+1.48	+1.47	1.56	2.61	1.32	2.27	1.72	2.73	1.47	2.42
Auriculo-vertex-auricular circumference	5.07	2.50	4.05	2.07	+4.55	+1.94	+3.43	+1.38	3.44	2.31	3.28	2.27	3.71	3.13	3.60	3.09
Vertical auriculo-vertex distance	1.94	2.60	1.43	2.07	+1.64	+1.76	+0.99	+1.11	1.55	2.29	1.53	2.44	1.60	3.77	1.59	3.90
Suboccipito-vertex-nasion circumference	3.12	1.52	2.55	1.28	+2.86	+1.31	+1.99	+0.84	2.60	1.54	2.49	1.54	2.78	2.15	2.66	2.11
Menton-bregma diameter	2.57	2.74	2.14	2.39	+2.21	+1.90	+1.67	+1.34	1.55	2.25	4.75	2.36	2.10	3.93	2.15	4.07

TABLE 164—*Continued*

Dimension	Graphic method								Method of averages				Method of least squares			
	Without regard to sign				With regard to sign				Without regard to sign				Without regard to sign			
	Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted	
	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.
Trunk – *concluded*																
Circumference at tenth rib	5.55	2.21	4.96	2.10	– 2.61	–0.47	– 2.13	– 0.23	10.43	4.68	9.36	4.37	11.62	5.66	10.50	5.35
Transverse diameter at tenth rib	1.74	2.14	1.34	1.83	– 1.28	–0.78	–0.83	–0.33	1.52	2.50	1.26	2.29	1.48	2.62	1.25	2.45
Antero-posterior diameter at tenth rib	2.86	3.94	2.27	3.26	– 2.28	– 1.62	– 1.60	–0.80	2.58	3.31	2.05	2.99	2.56	3.28	2.03	2.91
Circumference at umbilicus	10.39	4.12	9.09	3.75	– 9.21	– 2.90	– 7.76	– 2.34	10.97	4.22	9.56	3.75	11.52	4.34	10.10	3.94
Transverse diameter at umbilicus	2.21	2.82	2.01	2.53	– 1.05	– 0.44	–0.78	–0.16	2.23	3.32	1.95	3.01	2.22	3.94	1.97	3.67
Antero-posterior diameter at umbilicus	4.22	5.70	3.68	5.22	– 3.28	– 2.82	– 2.65	– 2.04	4.35	5.72	3.77	5.19	4.35	5.80	3.75	5.15
Sternal notch to pubis	4.59	3.56	3.97	3.16	– 2.49	– 1.34	– 1.80	–0.87	0.78	1.28	0.72	1.18	0.86	1.76	0.82	1.69
Sternal notch to umbilicus	3.51	3.32	3.07	3.10	– 3.35	– 2.87	– 2.87	– 2.45	2.64	2.77	2.29	2.55	3.52	3.58	3.05	3.26
Sternal notch to xiphi-sternal junction	0.74	3.82	0.71	3.79	–0.10	– 0.56	–0.05	–0.30	0.69	3.90	0.65	3.76	0.70	3.79	0.66	3.70
Xiphi-sternal junction to pubis	2.51	3.36	2.20	3.16	– 1.67	–0.68	– 1.33	–0.53	1.51	2.00	1.35	1.96	1.56	2.13	1.37	2.08
Xiphi-sternal junction to umbilicus	1.79	3.68	1.60	3.67	– 1.35	– 1.88	– 1.14	– 1.86	1.40	3.27	1.23	3.19	1.54	3.29	1.34	3.21
Umbilicus to pubis	1.97	7.03	1.73	6.96	– 1.41	–2.17	– 1.16	– 1.68	1.10	3.85	1.00	3.66	1.07	3.72	0.97	3.56
Pelvis																
Height of pelvis (crest of ilium to rump)	0.68	2.48	0.67	2.46	+ 0.32	+0.12	+0.36	+0.28	0.61	2.10	0.56	2.00	0.58	2.18	0.53	2.07
Interspinous diameter	0.93	1.67	0.77	1.48	– 0.47	–0.33	–0.29	–0.05	0.91	1.82	0.78	1.68	0.93	2.12	0.81	2.01
Intercristal diameter	1.28	2.58	1.10	2.54	–0.66	+0.24	–0.36	+0.77	1.04	2.25	0.86	2.08	1.06	2.21	0.88	2.06
Intertrochanteric diameter	1.87	3.08	1.50	2.68	– 1.13	–0.24	–0.77	+ 0.15	1.55	3.52	1.39	3.30	1.60	3.84	1.45	3.62
External conjugate diameter	2.02	4.39	1.51	3.62	– 1.48	– 1.59	– 1.10	– 0.79	2.48	5.08	2.07	4.45	2.78	6.38	2.35	5.86
Bi-tuberous distance	1.63	13.34	1.27	10.01	–0.65	–0.09	–0.36	+ 1.73	1.19	11.16	1.05	10.71	1.24	11.74	1.11	11.52

TABLE 164—*Continued*

Dimension	Graphic method								Method of averages				Method of least squares			
	Without regard to sign				With regard to sign				Without regard to sign				Without regard to sign			
	Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted	
	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.
Head and Neck - *concluded*																
Bi-malar distance (or diameter)	1.00	4.37	0.96	4.29	+0.10	+2.75	+0.09	+2.71	0.65	1.68	0.59	1.61	0.65	1.69	0.60	1.62
Bi-auricular diameter	1.80	3.71	1.63	3.59	+0.92	+1.11	+0.51	+0.32	1.13	3.67	1.21	3.75	1.39	4.53	1.45	4.60
Auriculo-vertex diameter	1.94	2.44	1.55	2.00	+1.86	+2.18	+1.44	+1.66	1.33	2.68	1.29	2.64	1.38	2.96	1.34	2.60
Nasion-menton distance	0.69	2.53	0.67	2.52	+0.23	+1.53	+0.32	+1.32	0.79	3.22	0.78	3.27	0.78	3.10	0.77	3.16
Vertical head height	1.04	1.39	0.96	1.42	+0.48	+0.57	+0.23	+0.32	1.39	2.27	1.29	2.37	1.48	2.66	1.45	2.76
Orbito-auricular distance	0.56	3.11	0.56	3.21	+0.02	+0.11	-0.11	-0.25	0.48	3.58	0.48	3.53	0.46	3.27	0.47	3.22
Orbito-auriculo-suboccipital diameter	0.63	1.67	0.63	1.40	+0.27	+0.54	+0.14	+0.37	0.76	1.85	0.76	1.92	0.76	1.84	0.75	2.02
Circumference of neck	3.79	3.03	2.85	2.66	-3.15	-1.53	-1.93	-0.53	6.19	4.92	4.86	4.36	7.19	6.19	5.74	5.70
Trunk																
Bi-acromial diameter	1.94	2.29	1.74	2.26	-0.76	-0.53	-0.44	-0.28	2.17	3.28	2.03	3.46	2.41	4.11	2.28	4.24
Nipple to nipple distance	1.70	3.50	1.44	3.11	-1.02	-0.54	-0.65	-0.01	1.12	2.56	1.00	2.44	1.16	3.33	1.11	3.38
Bi-deltoid circumference	7.40	2.70	5.94	2.44	-5.90	-1.46	-3.92	-0.69	6.45	2.58	5.28	2.31	7.75	3.10	6.18	2.67
Bi-deltoid diameter	2.30	2.15	1.85	1.84	-1.46	-0.97	-0.95	-0.59	2.26	2.26	1.86	2.00	2.26	2.75	1.93	2.60
Circumference at nipples	4.61	2.00	3.70	1.78	-3.75	-1.40	-2.81	-1.06	4.74	2.00	3.82	1.85	4.61	1.89	3.71	1.74
Transverse diameter at nipples	1.22	0.10	1.06	1.81	-0.34	-0.01	-0.29	-0.11	1.09	1.68	0.92	1.52	1.22	2.04	1.06	2.08
Antero-posterior diameter at nipples	1.33	3.02	1.25	3.27	+0.05	+1.24	+0.15	+1.55	1.18	3.11	1.59	3.87	1.45	2.96	1.55	3.68
Circumference at xiphi-sternal junction	5.33	2.55	4.90	2.46	-3.13	-1.55	-2.53	-1.37	7.10	3.63	9.67	3.69	7.38	3.86	10.02	3.85
Transverse diameter at xiphi-sternal junc.	1.35	2.15	1.13	2.00	-0.35	+0.39	-0.18	+0.57	1.23	1.59	1.01	1.51	1.21	1.70	0.99	1.51
Antero-posterior diam. at xiphi-sternal junc	1.51	2.64	1.37	2.71	-0.57	-0.28	-0.45	-0.17	1.57	2.85	1.42	2.93	1.54	2.72	1.39	2.77

TABLE 164—*Concluded*

Dimension	Graphic method								Method of averages				Method of least squares			
	Without regard to sign				With regard to sign				Without regard to sign				Without regard to sign			
	Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted		Unweighted		Weighted	
	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.	Mm.	Per cent.
Extremities																
Length of upper extremity	1.07	1.09	1.12	1.20	-0.19	+0.01	-0.38	-0.19	1.15	1.40	1.15	1.45	1.16	1.42	1.16	1.11
Length of arm (acromion to elbow)	0.72	1.71	0.69	1.69	+0.10	+0.01	-0.08	-0.33	0.61	2.04	0.64	2.08	0.61	2.14	0.64	2.18
Length of forearm	0.64	1.88	0.62	1.94	-0.18	-0.04	+0.02	-0.50	0.49	2.20	0.50	2.12	0.48	2.11	0.49	2.04
Length of hand	0.59	2.77	0.51	2.44	-0.05	-0.17	-0.01	+0.20	0.52	2.94	0.43	2.35	0.54	2.16	0.57	1.94
Length of middle finger	0.36	4.64	0.34	3.69	-0.02	-2.36	+0.04	-1.21	0.38	4.38	0.36	3.58	0.44	4.27	0.42	3.58
Circumference of arm	2.30	4.33	1.87	3.26	-1.80	-3.39	-1.34	-2.21	2.26	3.66	1.88	2.96	2.28	3.73	1.87	2.84
Circumference of forearm	2.19	3.62	1.74	2.55	-2.03	-3.16	-1.52	-1.94	2.13	3.57	1.82	2.63	2.05	3.54	1.74	2.42
Circumference of wrist	1.14	3.91	1.22	3.55	+0.18	+0.09	+0.46	+1.64	1.08	5.61	1.03	3.50	1.11	5.66	1.10	3.65
Length of lower extremity	1.45	1.83	1.28	1.69	+0.53	+0.03	+0.32	+0.83	1.48	1.56	1.33	1.49	1.27	0.95	1.04	1.13
Length of thigh (post.-sup. iliac spine to knee)	0.83	1.39	0.76	1.21	-0.27	+0.19	-0.27	-0.06	0.78	1.31	0.75	1.25	0.77	1.15	0.78	1.23
Length of thigh (trochanter to knee)	0.63	1.29	0.63	1.42	-0.15	-0.25	-0.35	-0.74	0.63	1.46	0.60	1.39	0.64	1.47	0.61	1.41
Length of leg (knee to lateral malleolus)	0.50	1.22	0.92	1.77	+0.06	-0.48	+0.34	-0.13	0.52	1.25	0.59	1.03	0.51	1.32	0.55	1.01
Height of foot	0.64	6.22	0.54	5.72	-0.38	-0.76	-0.24	+0.58	0.49	7.27	0.41	5.66	0.56	8.63	0.48	6.93
Length of foot	0.73	4.00	0.61	3.12	-0.19	-2.20	-0.17	-1.49	0.69	3.80	0.61	3.15	0.64	3.56	0.61	3.19
Circumference of thigh	3.57	4.09	2.94	3.11	-2.47	-2.83	-1.76	-1.68	3.67	4.73	3.05	3.65	3.73	5.13	3.11	3.98
Circumference of calf	2.41	5.31	1.93	2.66	-1.93	-3.81	-1.43	-0.78	2.40	5.41	1.99	3.06	2.49	5.26	2.13	3.48

TABLE 165

Root Mean Square Deviations of the Calculated Values of the Various External Dimensions of the Body (as determined from the Formulae given in Table 163) from the Corresponding Observed Values for Five Centimeter Range Averages of Crown-heel Length in the Fetal Period

Dimension	Number of range averages used in obtaining the formula	Graphic method		Method of averages		Method of least squares	
		Deviations from averages used in formula (mm.)	Deviations from all averages (mm.)	Deviations from averages used in formula (mm.)	Deviations from all averages (mm.)	Deviations from averages used in formula (mm.)	Deviations from all averages (mm.)
General							
Sitting-height (crown-rump length)	10	4.87	4.87	3.77	3.77	3.72	3.72
Spine length	7	1.61	4.90	1.48	6.24	1.43	5.28
Crown to umbilicus	8	2.56	2.34	2.56	2.46	2.54	2.27
Crown to suprasternal notch	10	4.98	4.98	0.99	0.99	0.89	0.89
Head and Neck							
Occipito-frontal circumference	7	1.87	6.92	1.85	6.93	1.84	6.98
Occipito-frontal diameter	7	0.93	3.85	0.92	3.44	0.92	3.45
Suboccipito-bregmatic circumference	7	2.78	6.58	2.63	7.29	2.29	6.60
Suboccipito-bregmatic diameter	7	1.04	3.29	0.78	2.88	0.78	2.83
Suboccipito-frontal circumference	7	3.52	1.80	2.85	6.93	2.85	6.86
Suboccipito-frontal diameter	7	1.11	3.68	1.00	3.69	1.00	3.21
Occipito-mental circumference	10	4.27	4.27	4.16	4.16	4.16	4.16
Occipito-mental diameter	7	0.94	1.15	0.89	1.32	0.84	1.13
Large circumference (menton-lambda)	7	12.84	2.46	10.05	7.98	9.55	11.14
Bi-parietal diameter	7	1.18	3.35	0.87	2.21	0.84	2.43
Auriculo-vertex-auricular circumference	8	8.65	9.03	5.48	4.30	5.26	4.55
Vertical auriculo-vertex distance	10	3.59	3.59	2.00	2.00	1.98	1.98
Suboccipito-vertex-nasion circumference	10	5.75	5.75	3.61	3.61	3.53	3.53
Menton-bregma diameter	6	4.87	4.01	3.44	2.10	2.92	2.35
Bi-malar distance (or diameter)	10	1.17	1.17	0.78	0.78	0.78	0.78
Bi-auricular diameter	7	3.26	2.25	2.32	1.26	2.01	1.64
Auriculo-vertex diameter	10	3.41	3.41	1.69	1.69	1.68	1.68
Nasion-menton distance	9	0.63	0.96	0.79	0.82	0.77	0.82
Vertical head height	9	2.89	1.76	2.39	1.52	2.35	1.57
Orbito-auricular distance	9	0.62	0.68	0.56	0.57	0.56	0.57
Orbito-auricular suboccipital diameter	10	0.94	0.94	0.82	0.82	0.82	0.82
Circumference of neck	7	5.36	6.32	4.19	9.02	3.98	10.25
Trunk							
Bi-acromial diameter	10	3.46	3.46	2.99	2.99	2.95	2.95
Nipple to nipple distance	8	1.45	3.12	1.33	1.73	1.21	1.42
Bi-deltoid circumference	7	1.56	13.78	1.94	12.57	1.92	14.28
Bi-deltoid diameter	8	1.70	4.82	1.62	4.56	1.53	4.27
Circumference at nipples	8	1.48	8.18	1.37	8.65	1.35	8.49
Transverse diameter at nipples	8	0.94	1.61	1.31	1.46	1.24	1.53
Antero-posterior diameter at nipples	8	1.16	1.58	0.90	2.00	0.89	1.91
Circumference at xiphi-sternal junction	8	6.75	7.49	4.24	11.18	4.23	11.53
Transverse diameter at xiphi-sternal junction	8	0.89	1.85	0.80	1.77	0.76	1.73

TABLE 165—*Concluded*

Root Mean Square Deviations of the Calculated Values of the Various External Dimensions of the Body (as determined from the Formulae given in Table 163) from the Corresponding Observed Values for Five Centimeter Range Averages of Crown-heel Length in the Fetal Period

Dimension	Number of range averages used in obtaining the formula	Graphic method		Method of averages		Method of least squares	
		Deviations from averages used in formula (mm.)	Deviations from all averages (mm.)	Deviations from averages used in formula (mm.)	Deviations from all averages (mm.)	Deviations from averages used in formula (mm.)	Deviations from all averages (mm.)
Trunk *(concluded)*							
Antero-posterior diam. at xiphi-sternal junc.	8	1.05	2.09	1.04	2.14	1.03	2.06
Circumference at tenth rib	8	12.57	9.51	8.76	16.34	8.60	17.83
Transverse diameter at tenth rib	8	2.16	3.14	1.52	2.11	1.49	1.98
Antero-posterior diameter at tenth rib	8	1.34	4.96	1.24	4.41	1.23	4.35
Circumference at umbilicus	7	2.77	19.26	2.06	20.32	1.92	21.02
Transverse diameter at umbilicus	8	3.12	3.91	2.14	3.51	2.07	3.25
Antero-posterior diameter at umbilicus	7	1.25	6.87	1.26	7.08	1.19	7.15
Sternal notch to pubis	5	0.94	8.22	1.08	11.53	0.95	10.82
Sternal notch to umbilicus	7	2.13	5.38	1.63	3.95	1.39	4.74
Sternal notch to xiphi-sternal junction	10	0.93	0.93	0.88	0.88	0.86	0.86
Xiphi-sternal junction to pubis	8	1.43	1.78	0.82	2.96	0.71	3.19
Xiphi-sternal junction to umbilicus	8	1.29	2.69	1.36	2.17	0.97	2.57
Umbilicus to pubis	8	1.95	3.20	0.80	1.59	0.73	1.73
Pelvis							
Height of pelvis (crest of ilium to rump)	10	1.23	1.23	0.71	0.71	0.71	0.71
Interspinous diameter	8	0.94	1.66	0.87	1.36	0.86	1.30
Intercristal diameter	8	0.62	2.24	0.40	1.84	0.36	1.90
Intertrochanteric diameter	8	1.85	3.30	1.32	2.26	1.32	2.24
External conjugate diameter	7	1.53	3.22	1.14	4.00	1.07	4.35
Bi-tuberous distance	8	1.30	2.05	1.00	1.56	0.97	1.43
Extremities							
Length of upper extremity	10	1.40	1.40	1.38	1.38	1.38	1.38
Length of arm (acromion to elbow)	10	0.93	0.93	0.75	0.75	0.75	0.75
Length of forearm	10	0.87	0.87	0.57	0.57	0.57	0.57
Length of hand	10	0.70	0.70	0.65	0.65	0.62	0.62
Length of middle finger	10	0.50	0.50	0.47	0.47	0.48	0.48
Circumference of arm	8	1.13	3.80	1.07	3.82	1.07	3.98
Circumference of forearm	8	0.84	3.50	1.19	3.41	1.18	3.29
Circumference of wrist	10	1.40	1.40	1.33	1.33	1.32	1.32
Length of lower extremity	10	1.78	1.78	1.73	1.73	1.59	1.59
Length of thigh (post.-sup. iliac spine to knee)	10	1.16	1.16	1.02	1.02	0.99	0.99
Length of thigh (trochanter to knee)	10	0.88	0.88	0.87	0.87	0.87	0.87
Length of leg (knee to lateral malleolus)	10	0.67	0.67	0.60	0.60	0.59	0.59
Height of foot	10	1.15	1.15	0.77	0.77	0.73	0.73
Length of foot	10	0.98	0.98	0.88	0.88	0.83	0.83
Circumference of thigh	7	1.91	6.62	1.86	6.41	1.85	6.31
Circumference of calf	8	1.37	4.13	1.32	3.81	1.29	4.09

TABLE 166

Comparative Variability of Observations on Certain External Dimensions of the Body in the Fetal Period (Based upon the parts of the progressions unaffected by artifacts)

Dimension	"s_1", root mean square deviation of observations about calculated line as determined by:			"s_0", root mean square deviation of observations about line of regression (mm.)	"DR" deviation ratio $\frac{s_1}{s_0}$		
	Graphic method (mm.)	Method of averages (mm.)	Method of least squares (mm.)		Graphic method (mm.)	Method of averages (mm.)	Method of least squares (mm.)
Occipito-frontal diameter	7.613	7.584	7.599	4.193	1.82	1.81	1.81
Bi-deltoid circumference	11.417	11.459	11.403	11.381	1.00	1.01	1.00
Length of upper extremity	6.814	6.771	6.788	6.700	1.02	1.01	1.01
Length of arm (acromion to elbow)	9.467	4.593	4.298	3.996	2.37	1.15	1.08
Length of lower extremity	7.420	7.392	7.403	7.380	1.00	1.00	1.00
Circumference of thigh	7.310	7.439	7.519	6.598	1.11	1.13	1.14
Transverse diameter at umbilicus	5.079	5.173	5.253	5.061	1.00	1.02	1.04
Circumference of wrist	4.153	4.174	4.158	4.151	1.00	1.01	1.00
Length of foot	5.326	5.287	5.294	4.887	1.09	1.08	1.08
Auriculo-vertex diameter	3.103	3.400	3.423	3.069	1.01	1.08	1.12
Circumference of neck	8.973	9.093	9.214	8.955	1.00	1.02	1.03
Antero-posterior diameter at nipples	4.597	4.825	4.672	4.542	1.01	1.06	1.03

TABLE 167

Comparative Variability of Observations on Certain External Dimensions of the Body in the Fetal Period which are Markedly Affected by Artifacts

Dimension	"s_1", root mean square deviation of observations about calculated line, for portions of progressions not affected by artifacts (mm.)	"s_1", root mean square deviation of observations about calculated line for portions of progressions affected by artifacts	
		With observations uncorrected for artifacts (mm.)	With observations corrected for artifacts (mm.)
Bi-deltoid circumference	11.417	29.7	22.7
Circumference of thigh	7.310	14.916	13.924
Transverse diameter at umbilicus	5.079	11.929	10.901
Circumference of neck	8.973	13.696	24.417

PART XIII

TABLES OF DATA OF OTHER INVESTIGATORS ON THE EXTERNAL DIMENSIONS OF THE BODY IN THE FETAL PERIOD

TABLE 168

Summary of Published Observations on the General Body Dimensions

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Crown-Rump Length				Distance from Crown to Umbilicus		Distance from Crown to Sternal Notch
	Lafaille 1893	Retzius 1904	Michaelis 1906	Mall 1910	Faucon 1897	Retzius 1904	Lafaille 1893
0-5	—	4.1 (4.9 - 1)	—	1.3 (1.6 - ?)	3.0 (4.6 -1)	—	—
5-10	—	5.5 (7.1 - 9)	—	5.5 (7.7 - ?)	—	4.6 (7.1 - 9)	—
10-15	—	8.2 (11.2 -6)	11.3 (14.9-13)	9.0 (13.1 - ?)	7.7 (12.2 -4)	7.0 (11.2-6)	—
15-20	12.2 (17.5 -2)	12.2 (17.2 - 9)	14.8 (22.3-21)	12.2 (18.0 - ?)	11.0 (18.6 - 4)	10.1 (17.2 -9)	5.6 (17.5-2)
20-25	13.9 (20.0 -1)	15.3 (22.4 -7)	18.8 (29.5-22)	15.1 (22.4 - ?)	12.6 (22.0 -9)	12.9 (22.4 -7)	6.0 (20.0-1)
25-30	19.1 (29.0 -2)	18.3 (27.0 - 17)	22.2 (33.1 -14)	18.0 (26.8 - ?)	15.5 (27.2 -8)	14.7 (27.0-7)	7.8 (29.0-2)
30-35	23.3 (32.7 -3)	—	26.0 (39.7-12)	21.6 (32.4 - ?)	17.6 (31.6 -6)	—	9.8 (32.7 -3)
35-40	26.8 (32.7 -3)	23.7 (35.5 -1)	28.9 (44.3-8)	24.5 (37.1 - ?)	20.0 (37.0 -1)	19.2 (35.5 -2)	9.9 (37.5 -2)
40-45	30.3 (42.6 -7)	—	—	28.4 (42.5 - ?)	25.0 (43.0 -1)	—	11.0 (42.6 - 7)
45-50	32.9 (47.5-70)	—	—	32.1 (47.7 - ?)	—	—	11.6 (47.5-70)
50-55	35.3 (50.9-64)	—	—	—	—	—	12.3 (50.9-64)

TABLE 169

Summary of Published Observations on the Horizontal Head Circumference

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Spiegelberg 1868	Sutugin 1875	Fehling 1875	Witzinger 1876	Lind 1876	Arnovljević 1884	Weisz 1897	Faucon 1897	Corrado 1899	Hasselwander 1903	Legou 1903	Retzius 1904	Michaelis 1906	Heuser 1912	Lutz 1913	Kjölseth 1913
0-5	—	—	—	—	—	—	—	3.4 (4.6-1)	—	—	—	3.55 (2.9-2)	—	—	—	—
5-10	—	—	—	—	—	—	—	—	—	—	—	6.3 (6.7-8)	6.0 (7.9-5)	—	—	—
10-15	—	—	—	—	—	10.0 (12.0-1)	—	—	10.8 (11.9-1)	10.2 (13.4-6)	9.8 (12.5-6)	9.6 (11.7-3)	10.9 (14.9-13)	8.0 (12.0-1)	—	—
15-20	—	—	—	—	—	14.0 (17.0-1)	—	12.5 (18.5-3)	10.7 (16.3-2)	12.0 (16.8-2)	12.1 (17.6-12)	14.3 (17.5-8	—	—	—	—
20-25	—	—	—	—	—	13.0 (20.0-1)	—	13.9 (22.1-7)	15.7 (22.5-2)	—	15.2 (22.5-29)	17.7 (22.0-6)	15.2 (22.3-21)	14.8 (22.3-4)	—	—
25-30	—	—	—	—	—	16.7 (26.3-3)	21.75 (29.3-?)	18.4 (27.7-7)	19.4 (28.5-9)	17.5 (28.0-1)	18.25 (27.0-26)	20.7 (27.0-7)	19.1 (29.5-22)	19.5 (28.0-1)	—	—
30-35	23.3 (30.3-8)	—	—	—	—	21.0 (32.5-2)	—	21.5 (32.4-4)	22.1 (32.5-21)	21.0 (32.2-8)	22.1 (33.2-22)	—	22.1 (33.1-14)	—	—	—
35-40	26.2 (37.8-7)	—	—	—	—	24.7 (36.0-3)	23.3 (36.4-?)	23.4 (36.3-4)	25.7 (37.8-35)	25.0 (37.1-9)	24.7 (35.4-5	27.1 (35.5-2)	25.2 (39.7-12)	—	28.0 (38.0-?)	—
40-45	29.5 (43.5-32)	30.6 (41.7-13)	29.7 (42.5-?)	—	30.6 (42.2-5)	28.3 (40.5-2)	30.9 (44.6-?)	26.0 (43.0-1)	28.65 (42.5-46)	28.0 (41.7-19)	—	—	27.7 (44.3-8)	28.9 (41.7-6)	31.0 (42.5-?)	30.2 (42.2-?)
45-50	29.5 (45.3-6)	33.5 (47.9-202)	32.4 (47.0-?)	32.6 (48.0?-68)	33.4 (47.9-43)	32.5 (46.5-2)	32.5 (47.0-?)	—	31.8 (47.4-53)	31.4 (46.9-20)	—	—	—	33.1 (48.2-8)	33.7 (47.7-?)	33.8 (48.2-?)
50-55	—	35.9 (52.1-11)	34.9 (52.0-?)	35.3 (50.6-28)	34.8 (51.2-82)	35.75 (52.0-2)	33.8 (50.0-?)	—	34.2 (51.8-81)	33.8 (51.1-10)	—	—	—	35.1 (50.5-41)	35.7 (52.4-?)	35.6 (51.1-?)

TABLE 170

Summary of Published Observations on the Occipito-Frontal Diameter

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Caspar 1854	Spondli 1857	Jousset 1877	Ribemont 1879	Depaul 1879	Solares 1881	Lafaille 1893	Faucon 1897	Weisz 1897	Corrado 1899	Legou 1903	Retzius 1904	Michaelis 1906	Heuser 1912	Kjölseth 1913	Friedenthal 1914
0- 5	—	—	—	—	—	—	—	1.3 (4.6-1)	—	—	—	1.14 (2.6-5)	1.4 (3.5-5)	—	—	—
5-10	—	—	—	—	—	—	—	—	—	—	2.5 (8.5-1)	2.1 (6.1-9)	2.5 (7.9-5)	—	—	2.1 (7.5-2)
10-15	—	—	—	—	—	—	—	2.25 (12.2-4)	—	3.3 (11.9-1)	3.1 (12.5-6)	3.2 (11.5-4)	4.0 (14.9-13)	3.3 (12.0-1)	—	3.7 (13.4-1)
15-20	—	—	4.75 (18.5-?)	—	—	—	4.6 (17.5-2)	4.17 (18.5-3)	—	—	4.2 (17.6-12)	4.9 (17.5-8)	—	—	—	—
20-25	—	—	5.5 (23.0-?)	—	—	—	5.5 (20.0-1)	4.62 (21.7-11)	—	5.8 (24.0-1)	5.2 (22.4-30)	5.85 (22.2-6)	5.5 (22.3-21)	5.75 (22.3-4)	—	5.4 (22.0-1)
25-30	—	—	6.7 (26.0-?)	—	—	—	7.2 (29.0-2)	6.2 (27.2-9)	7.4 (29.3-?)	6.5 (28.7-7)	6.2 (27.0-28)	7.0 (27.0-7)	6.9 (29.5-22)	6.5 (28.1-1)	—	—
30-35	—	—	7.1 (31.2-?)	—	—	—	9.4 (32.7-3)	6.95 (31.6-6)	—	7.2 (32.5-14)	7.3 (33.2-22)	—	7.9 (33.1-14)	—	—	8.05 (30.2-1)
35-40	—	9.15 (39.2-1)	9.25 (37.8-?)	—	—	—	8.85 (37.5-2)	8.0 (36.3-4)	7.8 (36.4-?)	8.2 (37.9-31)	8.2 (35.5-6)	9.15 (35.5-2)	8.9 (39.7-12)	—	—	9.6 (36.6-2)
40-45	10.9 (44.0-21)	11.35 (44.3-19)	—	10.78 (43.0-20)	—	—	10.2 (42.6-7)	—	10.5 (44.6-?)	9.3 (42.6-43)	—	—	10.6 (44.3-8)	9.8 (41.7-6)	10.8 (42.5-?)	—
45-50	10.8 (48.2-106)	11.8 (47.8-74)	—	11.44 (47.2-104)	11.5 (48.2-98)	11.5 (48.3-40)	11.4 (47.5-70)	—	10.85 (47.0-?)	10.3 (47.4-53)	—	—	—	11.05 (48.2-8)	11.5 (48.2-?)	12.0 (47.0-1)
50-55	11.1 (52.4-79)	12.2 (52.3-6)	—	11.9 (51.7-81)	11.9 (50.9-102)	11.9 (51.0-57)	11.7 (50.9-64)	—	11.4 (50.0-?)	11.3 (51.8-80)	—	—	—	12.1 (50.5-41)	12.0 (51.1-?)	11.6 (50.1-1)

TABLE 171

Summary of the Published Observations on the Suboccipito-Bregmatic and Suboccipito-Frontal Diameters, and the Suboccipito-Bregmatic Circumference

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Suboccipito-Bregmatic Diameter								Suboccipito-Frontal Diameter			Suboccipito-Bregmatic Circumference			
	Ribemont 1879	Depaul 1879	Solares 1881	Lafaille 1893	Weisz 1897	Legou 1903	Michaelis 1906	Kjölseth 1913	Lafaille 1893	Faucon 1897	Legou 1903	Ribemont 1879	Faucon 1897	Weisz 1897	Legou 1903
0-5	—	—	—	—	—	—	—	—	—	1.2 (4.6-1)	—	—	3.4 (4.6-1)	—	—
5-10	—	—	—	—	—	2.5 (8.5-1)	—	—	—	—	2.4 (8.5-1)	—	—	—	—
10-15	—	—	—	—	—	3.05 (12.5-6)	3.4 (14.9-13)	—	—	2.25 (12.2-4)	3.3 (12.5-6)	—	—	—	9.6 (12.5-6)
15-20	—	—	—	3.55 (17.5-2)	—	4.0 (17.6-12)	—	—	—	4.2 (18.5-3)	4.2 (17.6-12)	—	13.2 (18.5-3)	—	12.0 (17.6-12)
20-25	—	—	—	5.2 (20.0-1)	—	4.9 (22.4-30)	5.0 (22.3-21)	—	—	4.5 (21.7-11)	5.2 (22.4-30)	—	14.0 (22.3-6)	—	14.55 (22.4-30)
25-30	—	—	—	6.75 (29.0-2)	6.4 (29.3-?)	5.8 (27.0-28)	6.2 (29.5-22)	—	6.8 (29.0-2)	5.95 (27.2-9)	6.1 (27.0-28)	—	18.4 (27.7-7)	20.25 (29.3-?)	18.25 (27.0-26)
30-35	—	—	—	8.2 (32.7-3)	—	6.6 (33.2-22)	6.7 (33.1-14)	—	8.9 (32.7-3)	6.5 (31.6-6)	7.1 (33.2-22)	—	21.5 (32.4-4)	—	21.2 (33.2-22)
35-40	—	—	—	7.85 (37.5-2)	7.0 (36.4-?)	7.6 (35.5-6)	8.1 (39.7-12)	—	8.0 (37.5-2)	7.3 (36.3-4)	7.8 (35.5-6)	—	22.4 (36.3-4)	21.2 (36.4-?)	23.3 (35.5-5)
40-45	9.3 (43.0-20)	—	—	8.9 (42.6-7)	8.75 (44.6-?)	—	8.6 (44.3-8)	8.7 (42.5-?)	9.3 (42.6-7)	—	—	29.2 (43.0-20)	25.0 (43.0-1)	28.65 (44.6-?)	—
45-50	9.7 (47.2-104)	9.5 (48.2-98)	9.5 (48.3-40)	9.5 (47.5-70)	9.1 (47.0-?)	—	—	9.8 (48.2-?)	10.3 (47.5-70)	—	—	31.3 (47.2-104)	—	29.5 (47.0-?)	—
50-55	10.15 (51.7-81)	9.8 (50.9-102)	9.8 (51.0-57)	9.9 (50.9-64)	9.5 (50.0-?)	—	—	10.0 (51.1-?)	10.9 (50.9-64)	—	—	32.3 (51.7-81)	—	—	—

TABLE 172

Summary of Published Observations on the Occipito-Mental Diameter and the Occipito-Mental and Suboccipito-Frontal Circumferences

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Occipito-Mental Diameter												Occipito-Mental Circumference		Suboccipito-Frontal Circumference	
	Spondli 1857	Ribemont 1879	Depaul 1879	Solares 1881	Lafaille 1893	Weisz 1897	Faucon 1897	Corrado 1899	Legou 1903	Michaelis 1906	Cadre 1910	Kjölseth 1913	Ribemont 1879	Weisz 1897	Faucon 1897	Legou 1903
0-5	—	—	—	—	—	—	1.5 (4.6-1)	—	—	1.4 (3.7-5)	—	—	—	—	3.4 (4.6-1)	—
5-10	—	—	—	—	—	—	—	—	2.8 (8.5-1)	2.5 (7.9-5)	—	—	—	—	—	—
10-15	—	—	—	—	—	—	2.7 (12.2-4)	3.6 (11.9-1)	3.4 (12.5-6)	3.8 (14.9-13)	—	—	—	—	—	9.6 (12.5-6)
15-20	—	—	—	—	5.0 (17.5-2)	—	4.8 (18.5-3)	—	4.6 (17.6-12)	—	—	—	—	—	12.8 (18.5-3)	12.1 (17.6-12)
20-25	—	—	—	—	5.9 (20.0-1)	—	5.4 (21.7-11)	6.9 (24.0-1)	6.1 (22.4-30)	5.3 (22.3-21)	—	—	—	—	14.2 (22.3-6)	15.2 (22.4-30)
25-30	—	—	—	—	7.6 (29.0-2)	8.55 (29.3-?)	7.0 (27.2-9)	7.5 (28.7-7)	7.1 (27.0-28)	6.7 (29.5-22)	—	—	—	25.5 (29.3-?)	18.3 (27.7-7)	18.2 (27.0-26)
30-35	—	—	—	—	10.5 (32.7-3)	—	7.7 (31.6-6)	8.5 (32.5-14)	8.3 (33.2-22)	8.0 (33.1-14)	—	—	—	—	21.6 (32.4-4)	21.6 (33.2-22)
35-40	10.5 (39.2-1)	—	—	—	9.75 (37.5-2)	9.0 (36.4-?)	9.0 (36.3-4)	9.7 (37.9-31)	9.5 (35.5-7)	9.0 (39.7-12)	—	—	—	26.7 (36.4-?)	22.75 (36.3-4)	24.1 (35.5-5)
40-45	12.7 (44.3-19)	11.9 (43.0-20)	—	—	11.4 (42.6-7)	12.4 (44.6-?)	11.5 (43.0-1)	10.7 (42.6-43)	—	10.0 (44.3-8)	—	11.65 (42.5-?)	34.45 (43.0-20)	34.6 (44.6-?)	26.0 (43.0-1)	—
45-50	13.3 (47.8-74)	12.6 (47.2-104)	13.3 (48.2-98)	13.2 (48.3-40)	12.5 (47.5-70)	12.9 (47.0-?)	—	12.0 (47.4-53)	—	—	13.6 (47.8-18)	12.9 (48.2-?)	37.0 (47.2-104)	36.05 (47.0-?)	—	—
50-55	14.1 (52.3-6)	13.1 (51.7-81)	13.7 (50.9-102)	13.6 (51.0-57)	13.2 (50.9-64)	13.35 (50.0-?)	—	13.1 (51.8-80)	—	—	14.1 (51.2-5)	13.45 (51.1-?)	38.4 (51.7-81)	37.45 (50.0-?)	—	—

TABLE 173

Summary of Published Observations on the Bi-Parietal Diameter

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Caspar 1854	Spondli 1857	Sutugin 1875	Calderini 1875	Jousset 1877	Depaul 1879	Ribemont 1879	Solares 1881	Lafaille 1893	Weisz 1897	Faucon 1897	Corrado 1899	Legou 1903	Retzius 1904	Michaelis 1906	Cadre 1910	Kjölseth 1913	Friedenthal 1914
0-5	—	—	—	—	—	—	—	—	—	—	0.6 (4.6-1)	—	—	1.0 (3.3-3)	1.1 (3.6-5)	—	—	—
5-10	—	—	—	—	—	—	—	—	—	—	—	—	2.0 (8.5-1)	1.8 (6.1-9)	2.5 (7.9-5)	—	—	1.7 (7.5-2)
10-15	—	—	—	—	—	—	—	—	—	—	1.75 (12.2-4)	2.7 (11.9-1)	2.6 (12.5-6)	2.6 (11.5-4)	3.0 (14.9-13)	—	—	3.1 (13.4-1)
15-20	—	—	—	—	4.0 (17.8-?)	—	—	—	3.6 (17.5-2)	—	3.3 (18.5-3)	—	3.5 (17.6-12)	4.0 (17.2-9)	—	—	—	—
20-25	—	—	—	—	4.5 (23.0-?)	—	—	—	4.5 (20.0-1)	—	3.9 (21.7-11)	4.4 (24.0-1)	4.1 (22.4-30)	4.8 (22.2-6)	4.3 (22.3-21)	—	—	4.2 (22.0-1)
25-30	—	—	—	—	6.0 (26.0-?)	—	—	—	5.9 (29.0-2)	6.15 (29.3-?)	5.0 (27.2-9)	5.0 (28.7-7)	4.9 (27.0-28)	5.7 (27.0-7)	5.3 (29.5-22)	—	—	—
30-35	—	—	—	—	6.2 (31.2-?)	—	—	—	8.0 (32.7-3)	—	5.5 (31.6-6)	5.65 (32.5-14)	5.9 (33.2-22)	—	6.1 (33.1-14)	—	—	5.5 (30.2-1)
35-40	—	7.85 (39.2-1)	—	6.4 (36.3-3)	7.4 (37.8-?)	—	—	—	6.95 (37.5-2)	6.8 (36.4-?)	6.6 (36.3-4)	6.7 (37.9-31)	6.6 (35.5-6)	7.55 (35.5-2)	6.5 (39.7-12)	—	—	6.5 (36.6-2)
40-45	8.6 (44.0-21)	8.7 (44.3-19)	8.2 (43.0-12)	7.4 (44.0-44)	—	—	8.7 (43.0-20)	—	8.4 (42.6-7)	8.4 (44.6-?)	7.0 (43.0-1)	7.6 (42.6-43)	—	—	7.9 (44.3-8)	—	7.8 (42.5-?)	—
45-50	8.7 (48.2-106)	9.1 (47.8-74)	8.8 (47.25-116)	8.75 (47.7-807)	—	9.2 (48.2-98)	9.25 (47.2-104)	9.3 (48.3-40)	9.1 (47.5-70)	8.7 (47.0-?)	—	8.5 (47.3-52)	—	—	—	9.1 (47.7-29)	8.9 (48.2-?)	8.4 (47.0-1)
50-55	8.5 (52.4-79)	9.15 (52.3-6)	9.4 (52.0-41)	—	—	9.6 (50.9-102)	9.6 (51.7-81)	9.6 (51.0-57)	9.5 (50.9-64)	9.15 (50.0-?)	—	9.1 (51.8-80)	—	—	—	9.55 (50.8-12)	9.3 (51.1-?)	9.05 (50.0-1)

TABLE 174

Summary of Published Observations on the Minor Head Dimensions

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Bi-Malar Diameter			Bi-Auricular Diameter		Nasion-Menton Distance		Vertical Head-Height		Auriculo-Vertex (Vertical)
	Sutugin 1875	Ribemont 1879	Retzius 1904	Retzius 1904	Friedenthal 1914	Retzius 1904	Friedenthal 1914	Lafaille 1893	Retzius 1904	Friedenthal 1914
0-5	—	—	—	—	—	0.45 (? -6)	—	—	1.3 (? - 7)	—
5-10	—	—	1.2 (6.7-6)	1.6 (7.1-9)	1.7 (7.5-2)	0.9 (6.9-8)	0.8 (7.5-2)	—	2.2 (7.1-9)	1.7 (7.5-2)
10-15	—	—	1.85 (11.5-4)	2.4 (11.3-5)	3.1 (13.4-1)	1.3 (11.2-6)	1.7 (13.4-1)	—	3.0 (11.2-6)	2.9 (13.4-1)
15-20	—	—	3.1 (17.5-8)	3.6 (17.2-9)	—	2.05 (17.6-8)	—	4.6 (17.5-2)	4.0 (17.2-9)	—
20-25	—	—	3.95 (22.2-6)	4.7 (22.2-6)	4.2 (21.9-1)	2.5 (22.2-6)	2.3 (22.0-1)	4.9 (20.0-1)	5.2 (22.2-6)	4.0 (22.0-1)
25-30	—	—	4.7 (27.0-7)	5.2 (27.0-7)	—	3.0 (27.0-7)	—	7.0 (29.0-2)	6.3 (27.0-6)	—
30-35	—	—	—	—	5.5 (30.2-1)	—	3.6 (30.2-1)	8.6 (32.7-3)	—	5.9 (30.2-1)
35-40	—	—	6.45 (35.5-2)	6.55 (35.5-2)	6.5 (36.6-2)	3.85 (35.5-2)	3.9 (36.6-2)	8.4 (37.5-2)	7.3 (35.5-2)	6.7 (36.6-2)
40-45	7.2 (43.0-12)	7.1 (43.0-19)	—	—	—	—	—	9.1 (42.6-7)	—	—
45-50	7.5 (43.7-116)	7.6 (47.2-105)	—	—	8.4 (47.0-1)	—	4.5 (47.0-1)	9.8 (47.5-70)	—	8.0 (47.0-1)
50-55	8.1 (52.0-41)	7.8 (51.1-82)	—	—	9.05 (50.1-1)	—	5.4 (50.1-1)	10.3 (50.9-64)	—	8.1 (50.1-1)

TABLE 175

Summary of Published Observations on the Dimensions of the Trunk

Large figures: average measurement (cm.); small figures, in parentheses, average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Bi-Acromial Diameter					Bi-Deltoid Diameter	Bi-Deltoid Circumference	Distance from Sternal Notch to Pubis		Distance from Sternal Notch to Umbilicus	Distance from Xiphisternal Junction to Umbilicus	Distance from Umbilicus to Pubis
	Caspar 1854	Lafaille 1893	Retzius 1904	Michaelis 1906	Friedenthal 1914	Lafaille 1893	Spiegelberg 1868	Lafaille 1893	Friedenthal 1914	Lafaille 1893	Retzius 1904	Retzius 1904
0-5	—	—	0.8 (4.9-6)	—	—	—	—	—	—	—	—	—
5-10	—	—	1.6 (7.1-9)	—	1.9 (7.6-2)	—	—	—	2.6 (7.6-2)	—	1.6 (7.2-2)	0.5 (6.5-2)
10-15	—	—	2.5 (11.2-6)	4.1 (14.9-3)	3.2 (13.4-1)	—	—	—	4.0 (13.4-1)	—	1.9 (11.0-4)	0.9 (11.0-4)
15-20	—	4.0 (17.5-2)	3.9 (17.2-9)	—	—	4.5 (17.5-2)	—	6.0 (17.5-2)	—	4.5 (17.5-2)	2.7 (16.9-8)	1.0 (16.9-8)
20-25	—	4.0 (20.0-1)	5.2 (22.4-7)	5.6 (22.8-21)	5.6 (21.9-1)	5.1 (20.0-1)	—	6.8 (20.0-1)	6.7 (21.9-1)	5.2 (20.0-1)	3.5 (22.4-7)	1.8 (22.4-7)
25-30	—	6.7 (29.0-2)	6.2 (27.0-7)	7.3 (29.5-22)	—	7.5 (29.0-2)	—	10.0 (29.0-2)	—	7.4 (29.0-2)	3.8 (27.1-5)	2.0 (27.0-7)
30-35	—	8.0 (32.7-3)	—	7.8 (33.1-14)	7.5 (30.2-1)	9.1 (32.7-3)	21.9 (30.4-8)	13.7 (32.7-3)	9.2 (30.2-1)	11.0 (32.7-3)	—	—
35-40	—	7.6 (37.5-2)	7.9 (35.5-2)	9.9 (39.7-12)	9.0 (36.6-2)	8.6 (37.5-2)	24.6 (37.8-7)	13.5 (37.5-2)	11.0 (36.6-2)	10.4 (37.5-2)	5.5 (35.5-2)	3.2 (35.5-2)
40-45	9.2 (44.5-1)	8.8 (42.6-88)	—	11.2 (44.3-8)	—	9.8 (42.6-88)	29.1 (43.5-32)	14.7 (42.6-7)	—	11.4 (42.6-7)	—	—
45-50	12.3 (48.2-41)	9.6 (47.5-96)	—	—	11.0 (47.0-1)	11.2 (47.5-96)	29.6 (45.3-6)	16.3 (47.5-70)	14.0 (47.0-1)	12.9 (47.5-70)	—	—
50-55	12.9 (52.4-74)	10.5 (50.9-105)	—	—	12.0 (50.0-1)	12.1 (50.9-105)	—	17.6 (50.9-64)	16.4 (50.0-1)	14.0 (50.8-63)	—	—

TABLE 176

Summary of Published Observations on the Dimensions of the Trunk

Large figures: average measurement (cm.); small figures, in parentheses, average crown-heel length and number of cases

C.H. Range (cm.)	Circumference of Thorax			Ant.-Post. Diameter of Thorax	Nipple to Nipple Distance	Circumference at Umbilicus	Intercristal Diameter		Intertrochanteric Diameter		
	Michaelis 1906	Heuser 1912	Linzenmeier 1914	Michaelis 1906	Lafaille 1893	Michaelis 1906	Lafaille 1893	Retzius 1904	Caspar 1854	Lafaille 1893	Friedenthal 1914
0-5	—	—	—	—	—	—	—	—	—	—	—
5-10	—	—	—	—	—	—	—	1.1 (7.1-9)	—	—	1.2 (7.6-2)
10-15	10.2 (14.9-13)	5.7 (12.0-1)	—	2.9 (14.9-13)	—	8.3 (14.9-13)	—	1.7 (11.2-6)	—	—	2.2 (13.4-1)
15-20	—	—	—	—	2.4 (17.5-2)	—	2.6 (17.5-2)	2.8 (17.2-9)	—	2.7 (17.5-2)	—
20-25	13.4 (22.3-21)	12.6 (22.3-4)	—	4.0 (22.3-21)	2.7 (20.0-1)	12.6 (22.3-21)	2.8 (20.0-1)	3.7 (22.4-7)	—	3.3 (20.0-1)	3.9 (21.9-1)
25-30	17.1 (29.5-22)	15.0 (28.0-1)	—	5.9 (29.5-22)	3.9 (29.0-2)	15.9 (29.5-22)	4.0 (29.0-2)	4.5 (27.0-7)	—	4.9 (29.0-2)	—
30-35	20.2 (33.1-14)	—	—	6.3 (33.1-14)	6.1 (32.7-3)	18.2 (33.1-14)	5.7 (32.7-3)	—	—	6.9 (32.7-3)	5.4 (30.2-1)
35-40	25.2 (39.7-12)	—	—	6.9 (39.7-12)	5.4 (37.5-2)	21.2 (39.7-12)	6.5 (37.5-2)	6.0 (35.5-1)	—	6.5 (37.5-2)	7.5 (36.6-2)
40-45	26.2 (44.3-8)	23.9 (41.7-6)	26.0 (43.0-1)	7.3 (44.3-8)	6.2 (42.6-7)	24.2 (44.3-8)	6.2 (42.6-7)	—	7.8 (44.5-1)	7.9 (42.6-7)	—
45-50	—	28.0 (48.2-8)	28.0 (47.7-7)	—	6.9 (47.5-70)	—	6.8 (47.5-70)	—	8.4 (48.2-41)	9.0 (47.5-70)	9.5 (47.0-1)
50-55	—	33.7 (50.5-4)	30.2 (51.3-32)	—	7.4 (50.9-64)	—	7.2 (50.9-64)	—	9.1 (52.4-74)	9.7 (50.9-64)	11.4 (50.0-1)

TABLE 177

Summary of Published Observations on the Length of the Upper and Lower Extremities

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length (cm.) and number of cases

C.H. Range (cm.)	Length of Upper Extremity							Length of Lower Extremity							
	Bürtscher 1877	Fridolin 1881	Lafaille 1893	Corrado 1899	Retzius 1904	Michaelis 1906	Friedenthal 1914	Bürtscher 1877	Fridolin 1881	Lafaille 1893	Corrado 1899	Retzius 1904	Michaelis 1906	Heuser 1912	Friedenthal 1914
0-5	—	—	—	—	1.1 (4.9-7)	—	—	—	—	—	—	—	—	—	—
5-10	3.5 (6.6-3)	—	—	—	2.5 (7.1-9)	—	3.1 (7.6-2)	3.5 (6.6-3)	—	—	—	1.8 (7.1-9)	—	—	2.3 (7.6-2)
10-15	5.2 (13.0-2)	—	—	5.1 (12.4-4)	4.1 (11.2-6)	6.1 (14.9-3)	5.5 (13.4-1)	5.3 (13.0-2)	—	—	4.4 (12.4-4)	3.3 (11.2-6)	5.4 (14.9-13)	3.9 (12.0-1)	5.0 (13.4-1)
15-20	7.1 (17.2-2)	—	7.4 (17.5-2)	6.8 (17.2-3)	6.7 (17.2-9)	—	—	7.6 (17.2-2)	—	—	6.2 (17.2-3)	5.5 (17.2-9)	—	—	—
20-25	9.5 (22.5-5)	—	9.7 (20.0-1)	9.0 (22.0-3)	9.0 (22.4-7)	9.4 (22.3-21)	9.2 (21.9-1)	10.0 (22.5-5)	—	—	8.4 (22.0-3)	7.3 (22.4-7)	8.2 (22.3-21)	7.6 (22.3-4)	9.1 (21.9-1)
25-30	11.7 (28.3-4)	—	12.9 (29.0-2)	11.2 (25.8-11)	10.9 (27.0-7)	12.2 (29.5-22)	—	12.9 (28.3-4)	—	—	10.5 (25.8-11)	8.9 (27.0-7)	11.1 (29.5-22)	9.5 (28.0-1)	—
30-35	—	—	16.6 (32.7-3)	13.3 (32.4-15)	—	13.9 (33.1-14)	13.0 (30.2-1)	—	—	—	12.8 (32.4-15)	—	12.8 (33.1-14)	—	12.2 (30.2-1)
35-40	—	15.9 (37.8-8)	15.9 (37.5-2)	14.9 (37.5-28)	14.4 (35.5-2)	16.2 (39.7-12)	16.1 (36.6-2)	—	18.1 (37.8-8)	—	14.4 (37.5-28)	11.9 (35.5-2)	15.1 (39.7-12)	—	15.3 (36.6-2
40-45	17.3 (40.5-1)	17.5 (42.7-14)	18.3 (42.6-7)	16.8 (42.2-37)	—	18.2 (44.3-8)	—	19.3 (40.5-1)	20.2 (42.7-14)	17.2 (42.6-7)	16.2 (42.2-37)	—	16.9 (44.3-8)	13.9 (41.7-6)	—
45-50	—	18.8 (47.6-109)	20.7 (47.5-70)	18.6 (46.9-37)	—	—	19.3 (47.0-1)	—	21.9 (47.6-109)	20.0 (47.5-70)	18.1 (46.9-37)	—	—	17.7 (48.2-8)	19.7 (47.0-1)
50-55	—	20.1 (51.1-4)	21.8 (50.9-64)	20.3 (51.6-52)	—	—	21.7 (50.0-1)	—	23.5 (51.1-4)	21.2 (50.9-64)	20.1 (51.6-52)	—	—	19.1 (50.5-41)	20.0 (50.0-1)

TABLE 178

Summary of Published Observations on the Segments of the Upper Extremity

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length & number of cases

C.H. Range (cm.)	Length of Arm					Length of Forearm				
	Burtscher 1877	Fridolin 1881	Lafaille 1893	Retzius 1904	Friedenthal 1914	Bürtscher 1877	Fridolin 1881	Lafaille 1893	Retzius 1904	Friedenthal 1914
0-5	—	—	—	—	—	—	—	—	—	—
5-10	1.5 (6.6-3)	—	—	1.1 (7.1-9)	1.4 (7.6-2)	1.2 (6.6-3)	—	—	0.8 (7.1-9)	0.9 (7.6-2)
10-15	2.1 (13.0-2)	—	—	1.7 (11.2-6)	2.2 (13.4-1)	1.6 (13.0-2)	—	—	1.3 (11.2-6)	1.9 (13.4-1)
15-20	3.0 (17.2-2)	—	2.8, 3.3 (17.5-2)	2.8 (17.2-9)	—	2.2 (17.2-2)	—	— (17.5-2)	2.2 (17.2-9)	—
20-25	3.9 (22.5-5)	—	4.0, 4.1 (20.0-1)	3.7 (22.4-7)	3.4 (21.9-1)	3.0 (22.5-5)	—	— (20.0-1)	3.0 (22.4-7)	3.2 (21.9-1)
25-30	4.8 (28.3-4)	—	5.2, 5.4 (29.0-2)	4.4 (27.0-7)	—	3.7 (28.3-4)	—	(29.0-2)	3.2 (27.0-7)	—
30-35	—	—	5.8, 6.6 (32.7-3)	—	4.7 (30.2-1)	—	—	(32.7-3)	—	4.5 (30.2-1)
35-40	—	6.3 (37.8-8)	5.6, 6.7 (37.5-2)	5.7 (35.5-2)	6.1 (36.6-2)	—	4.7 (37.8-8)	— (37.5-2)	4.3 (35.5-2)	5.1 (36.6-2)
40-45	6.9 (40.5-1)	6.9 (42.7-14)	7.3, 7.9 (42.6-7)	—	—	5.0 (40.5-1)	5.2 (42.7-14)	6.9 (42.6-7)	—	—
45-50	—	7.4 (47.6-109)	7.8, 8.5 (47.5-70)	—	7.1 (47.0-1)	—	5.5 (47.6-109)	7.6 (47.5-70)	—	6.1 (47.0-1)
50-55	—	8.0 (51.1-4)	8.3, 8.9 (50.9-64)	—	10.1 (50.0-1)	—	5.8 (51.1-4)	8.1 (50.9-64)	—	5.7 (50.0-1)

C.H. Range (cm.)	Length of Hand							Length of Middle Finger
	Burtscher 1877	Fridolin 1881	Lodoli 1887	Lafaille 1893	Corrado 1899	Retzius 1904	Friedenthal 1914	Lafaille 1893
0-5	—	—	—	—	—	—	—	—
5-10	0.8 (6.6-3)	—	—	—	—	0.7 (7.1-9)	0.8 (7.6-2)	—
10-15	1.5 (13.0-2)	—	—	—	—	1.1 (11.2-6)	1.6 (13.4-1)	—
15-20	1.8 (17.2-2)	—	—	1.7 (17.5-2)	1.4 (16.3-2)	1.8 (17.2-9)	—	1.0 (17.5-2)
20-25	2.6 (22.5-5)	—	—	2.7 (20.0-1)	—	2.5 (22.4-7)	2.6 (21.9-1)	1.3 (20.0-1)
25-30	3.3 (28.3-4)	—	—	3.5 (29.0-2)	3.0 (27.3-6)	3.1 (27.0-7)	—	2.0 (29.0-2)
30-35	—	—	—	4.8 (32.7-3)	3.8 (32.2-7)	—	3.9 (30.2-1)	2.9 (32.7-3)
35-40	—	4.8 (37.8-8)	4.7 (38.0-2)	4.7 (37.5-2)	4.5 (37.8-19)	4.3 (35.5-2)	5.0 (36.6-2)	2.3 (37.5-2)
40-45	5.4 (40.5-1)	5.4 (42.7-14)	5.1 (42.0-1)	5.3 (42.6-7)	5.3 (42.7-20)	—	—	3.1 (42.6-7)
45-50	—	5.9 (47.6-109)	6.0 (48.1-18)	6.1 (47.5-70)	5.9 (47.4-25)	—	6.1 (47.0-1)	3.5 (47.5-70)
50-55	—	6.2 (51.1-4)	6.8 (51.1-38)	6.4 (50.9-64)	6.6 (51.6-39)	—	5.9 (50.0-1)	3.7 (50.9-64)

TABLE 179

Summary of Published Observations on the Segments of the Lower Extremity

Large figures: average measurement (cm.); small figures, in parentheses: average crown-heel length & number of cases

C.H. Range (cm.)	Length of Thigh					Length of Leg			Length of Leg and Height of Foot	
	Burtscher 1877	Fridolin 1881	Lafaille 1893	Retzius 1904	Friedenthal 1914	Bürtscher 1877	Fridolin 1881	Friedenthal 1914	Lafaille 1893	Retzius 1904
0-5	—	—	—	—	—	—	—	—	—	—
5-10	1.7 (6.6-3)	—	—	1.1 (7.1-9)	1.2 (7.6-2)	1.1 (6.6-3)	—	1.0 (7.6-2)	—	1.1 (7.1-9)
10-15	2.3 (13.0-2)	—	—	1.7 (11.2-6)	2.4 (13.4-1)	1.7 (13.0-2)	—	2.2 (13.4-1)	—	1.9 (11.2-6)
15-20	3.2 (17.2-2)	—	3.15 (17.5-2)	3.2 (17.2-9)	—	2.5 (17.2-2)	—	—	3.1 (17.5-2)	3.3 (17.2-4)
20-25	4.3 (22.5-3)	—	3.8 (20.0-1)	4.1 (22.4-7)	4.1 (21.9-1)	3.2 (22.5-5)	—	4.1 (21.9-1)	4.2 (20.0-1)	4.5 (22.4-7)
25-30	5.3 (28.3-4)	—	6.15 (29.0-2)	5.1 (27.0-7)	—	4.2 (28.3-4)	—	—	6.2 (29.0-2)	5.5 (27.0-7)
30-35	—	—	8.0 (32.7-3)	—	6.0 (30.2-1)	—	—	5.9 (30.2-1)	8.3 (32.7-3)	—
35-40	—	7.5 (37.8-8)	7.5 (37.5-2)	7.0 (35.5-2)	7.1 (36.6-2)	—	5.9 (37.8-8)	7.2 (36.6-2)	8.0 (37.5-2)	7.4 (35.5-2)
40-45	7.9 (40.5-1)	8.3 (42.7-14)	8.8 (42.6-7)	—	—	6.2 (40.5-1)	6.5 (42.7-14)	—	9.6 (42.6-7)	—
45-50	—	9.0 (47.6-109)	9.8 (47.5-70)	—	8.8 (47.0-1)	—	7.0 (47.6-109)	8.8 (47.0-1)	11.0 (47.5-70)	—
50-55	—	9.8 (51.1-4)	10.5 (50.9-64)	—	10.1 (50.0-1)	—	7.5 (51.1-4)	7.6 (50.0-1)	11.8 (50.9-64)	—

C.H. Range (cm.)	Length of Foot								Foot Height	
	Burtscher 1877	Fridolin 1881	Lafaille 1893	Corrado 1899	Hasselwander 1903	Retzius 1904	Heuser 1912	Friedenthal 1914	Lafaille 1893	Friedenthal 1914
0-5	—	—	—	—	—	—	—	—	—	—
5-10	0.8 (6.6-3)	—	—	—	—	0.8 (7.1-9)	—	0.9 (7.6-2)	—	0.3 (7.6-2)
10-15	1.3 (13.0-2)	—	—	—	1.6 (13.4-6)	1.3 (11.2-6)	1.0 (12.0-1)	1.5 (13.4-1)	—	0.4 (13.4-1)
15-20	1.9 (17.2-2)	—	1.9 (17.5-2)	1.7 (16.3-2)	1.7 (17.5-2)	2.2 (17.2-9)	—	—	0.6 (17.5-2)	—
20-25	2.5 (22.5-5)	—	3.1 (20.0-1)	—	2.6 (21.1-4)	3.1 (22.4-7)	2.9 (22.3-4)	3.4 (21.9-1)	1.2 (20.0-1)	1.0 (21.9-1)
25-30	3.3 (28.3-4)	—	3.9 (29.0-2)	3.7 (27.3-6)	2.8 (26.5-5)	3.8 (27.0-7)	3.8 (28.0-1)	—	1.4 (29.0-2)	—
30-35	—	—	6.1 (32.7-3)	4.5 (32.2-7)	4.4 (32.3-11)	—	—	4.7 (30.2-1)	1.9 (32.7-3)	1.3 (30.2-1)
35-40	—	4.8 (37.8-8)	5.7 (37.5-2)	5.6 (37.8-19)	5.5 (37.1-9)	5.5 (35.5-2)	—	5.7 (36.6-2)	2.0 (37.5-2)	1.5 (36.6-2)
40-45	5.2 (40.5-1)	5.4 (42.7-14)	6.4 (42.6-7)	6.6 (42.7-20)	6.2 (41.4-19)	—	6.5 (41.7-6)	—	2.1 (42.6-7)	—
45-50	—	5.9 (47.6-109)	7.3 (47.5-70)	7.2 (47.4-25)	7.1 (46.4-11)	—	7.7 (48.2-8)	6.6 (47.0-1)	2.5 (47.5-70)	2.1 (47.0-1)
50-55	—	6.3 (51.1-4)	7.7 (50.9-63)	8.0 (51.6-39)	7.4 (51.0-6)	—	8.5 (50.5-41)	6.3 (50.0-1)	2.6 (50.9-64)	2.3 (50.0-1)

TABLE 180

Summary of Reicher's Observations on Various External Dimensions of the Body in the Fetal Period

Crown-heel range (cm.)	Crown-rump length (mean)	Sternal notch to pubis	Length of upper extremity	Length of lower extremity
0 – 5	3.9 (4.4 - 3)	1.6 (4.3 - 8)	1.7 (4.3 - 7)	1.1 (4.3 - 6)
5 – 10	5.8 (7.6 - 65)	2.5 (7.6 - 75)	3.1 (7.7 - 73)	2.3 (7.7 - 70)
10 – 15	9.1 (12.0 - 35)	4.1 (12.4 - 57)	5.5 (12.4 - 55)	4.4 (12.5 - 59)
15 – 20	13.0 (17.9 - 23)	5.8 (17.6 - 34)	7.8 (17.6 - 32)	6.6 (17.7 - 34)
20 – 25	15.9 (22.4 - 24)	7.1 (22.3 - 26)	9.8 (22.2 - 28)	8.3 (22.2 - 27)
25 – 30	18.3 (26.7 - 11)	8.5 (26.7 - 11)	11.7 (26.7 - 11)	9.9 (26.7 - 11)
30 – 35	22.0 (32.6 - 7)	10.5 (32.6 - 7)	13.9 (32.6 - 7)	12.2 (32.6 - 7)
35 – 40	24.5 (36.1 - 5)	11.7 (36.1 - 5)	15.5 (36.1 - 5)	13.5 (36.1 - 5)
40 – 45	28.1 (41.7 - 3)	14.0 (41.7 - 3)	18.0 (41.7 - 3)	15.6 (41.7 - 3)

PART XIV

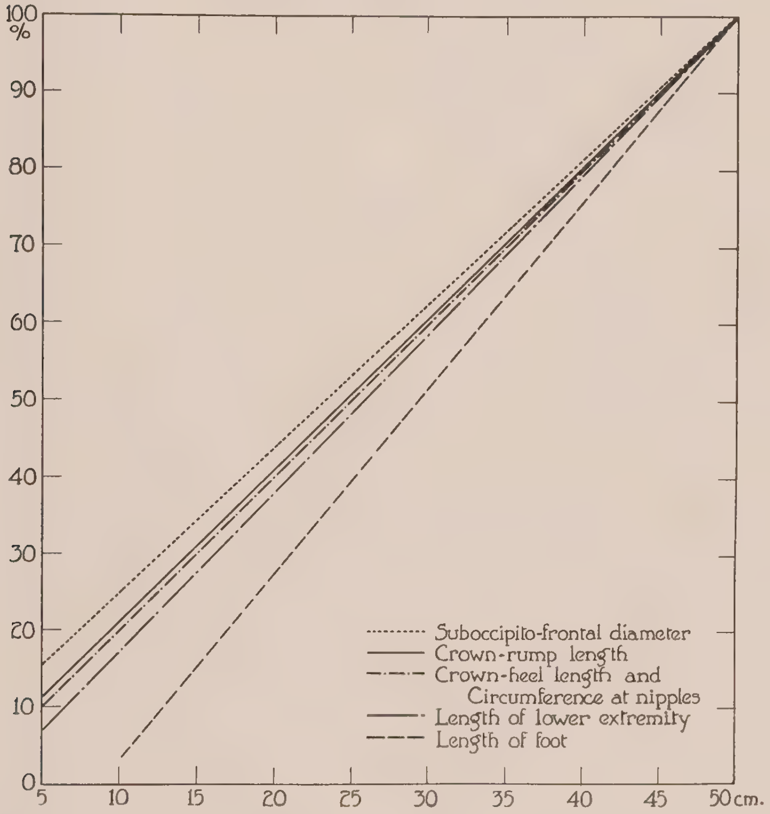
GENERAL GRAPHS AND FIGURES

A series of general graphs illustrating the relative growth of various typical dimensions of the body in the fetal period.

A series of histograms illustrating the changes in size and external form of the body in the fetal period.

FIGURE 67

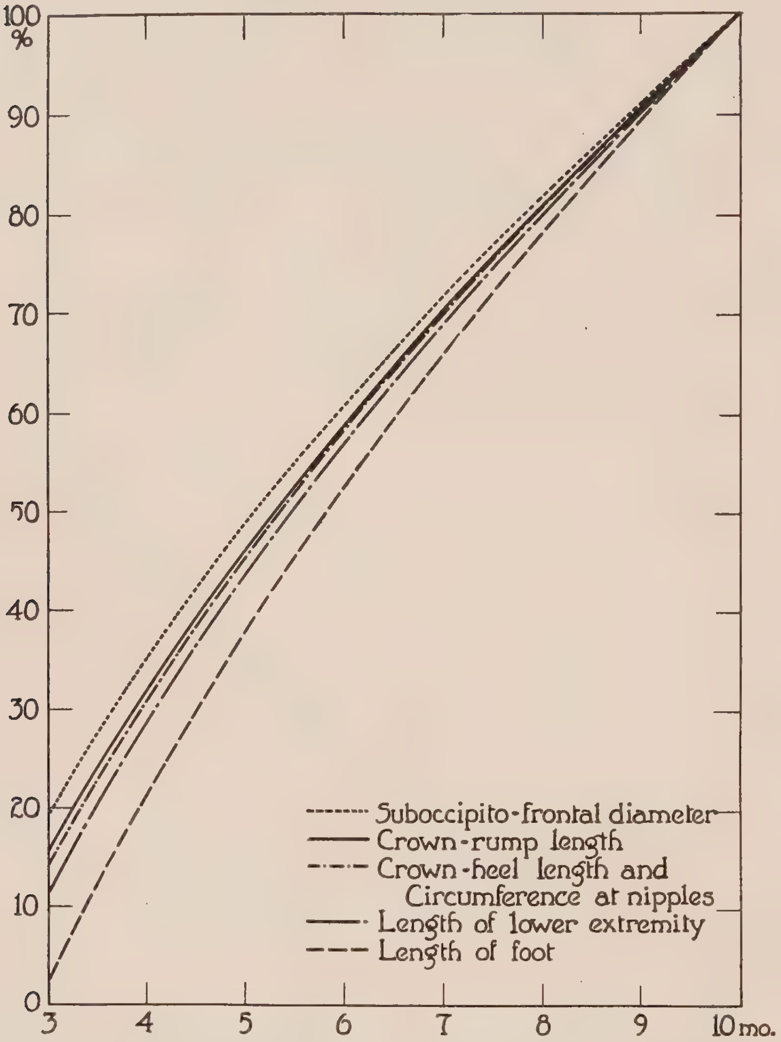
THE COMPARATIVE GROWTH OF CERTAIN OF THE EXTERNAL DIMENSIONS OF THE BODY IN RELATION TO THE CROWN-HEEL BODY-LENGTH IN THE FETAL PERIOD



All of these dimensions are reduced to a common scale by computing their values at each 5 cm interval of body-length as per cents of their respective values at 50 cm crown-heel length. The computations were made with the empirical formula for each of the several dimensions. Abscissa: Crown-heel length (cm). Ordinates: Per cents of values at 50 cm crown-heel length.

FIGURE 68

The Comparative Growth in the Fetal Period of the Various Dimensions Shown in Figure 67



In this figure the values are plotted against age in fetal or lunar months (as determined by the empirical formula of Scammon and Calkins for the computation of age from the crown-heel length).

FIGURE 69

THE MAXIMUM AND MINIMUM MONTHLY PERCENTAGE INCREMENTS MADE BY THE SEVERAL DIMENSIONS OF VARIOUS REGIONS OF THE BODY IN THE SUCCESSIVE MONTHS OF THE FETAL PERIOD

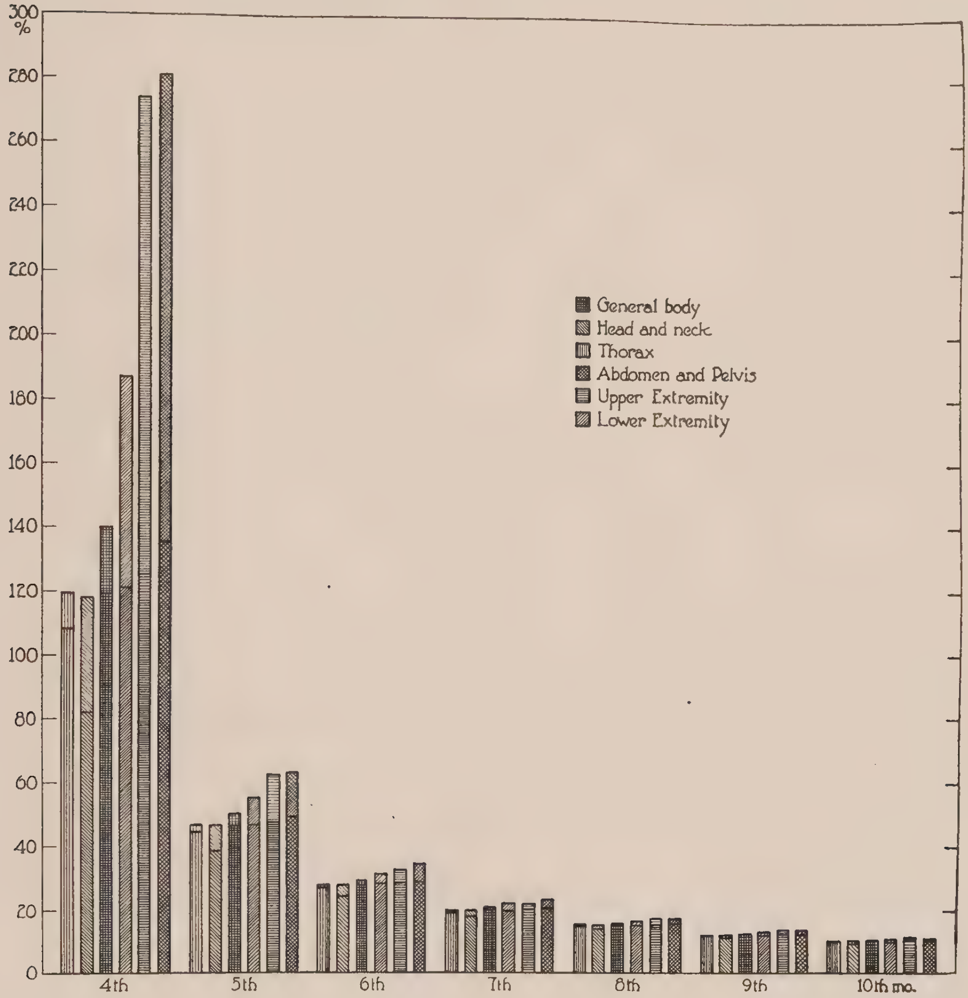
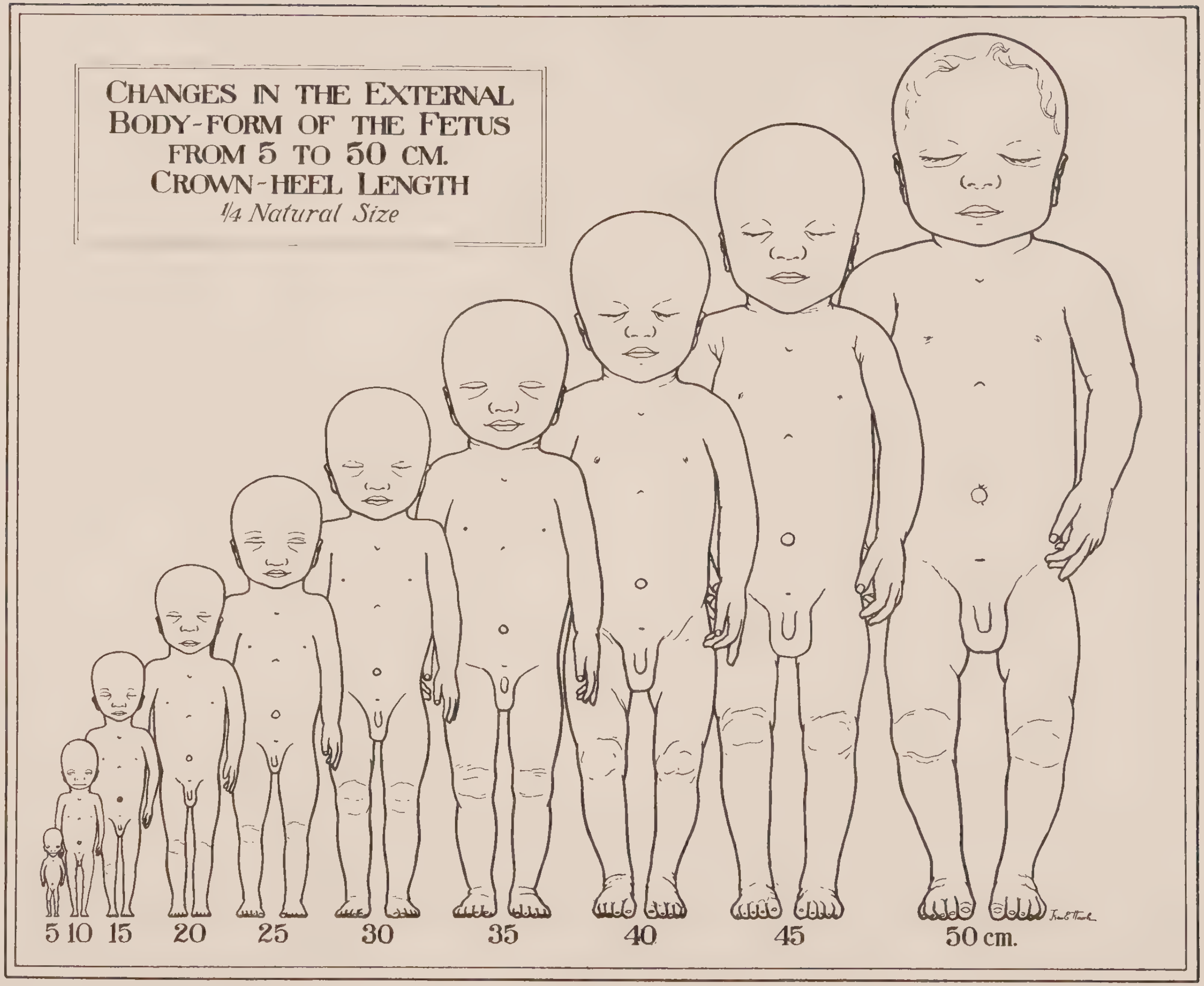
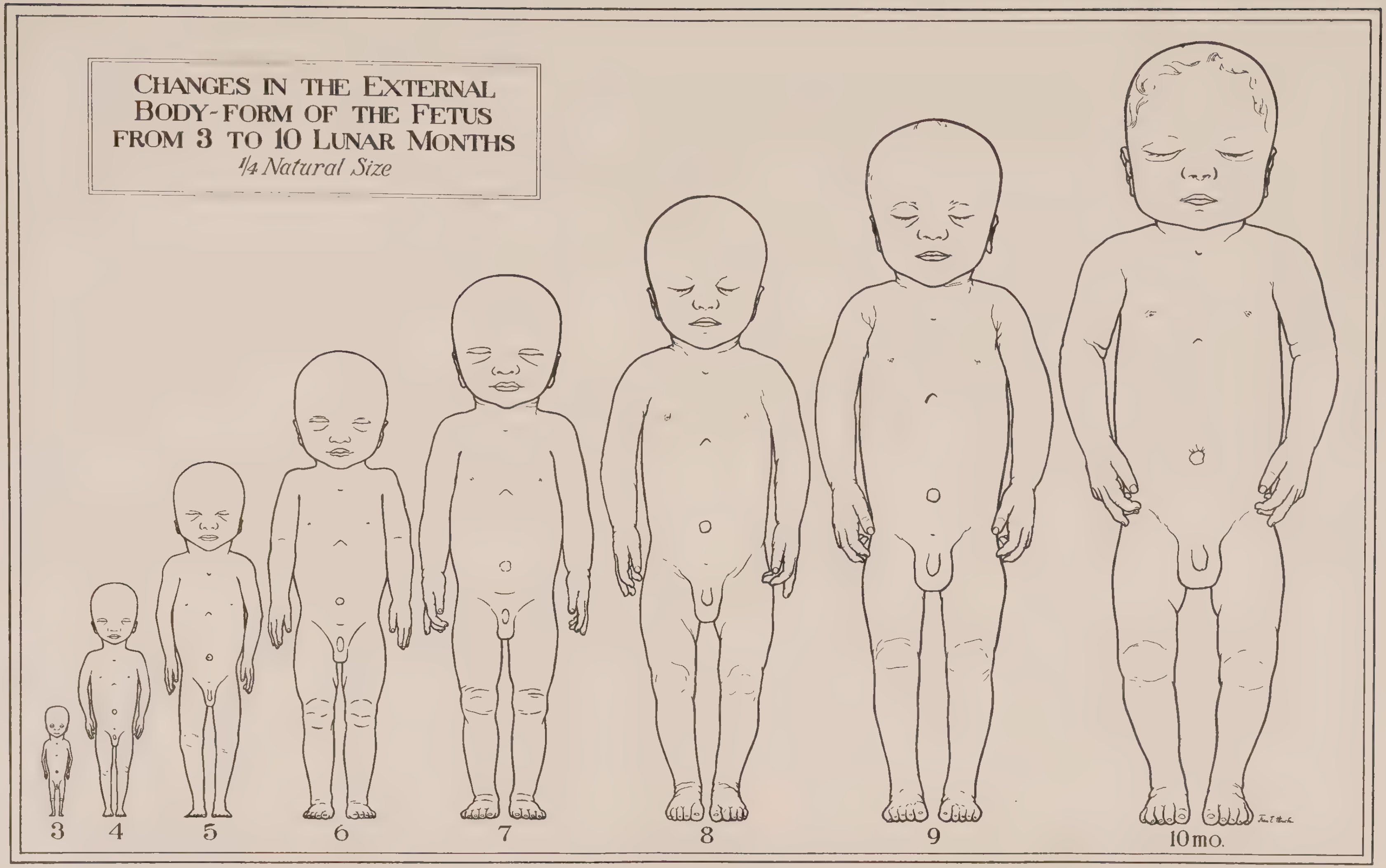


FIGURE 70


CHANGES IN THE EXTERNAL BODY-FORM OF THE FETUS FROM 5 TO 50 CM. CROWN-HEEL LENGTH
1/4 Natural Size
5
10
15
20
25
30
35
40
45
50 cm.

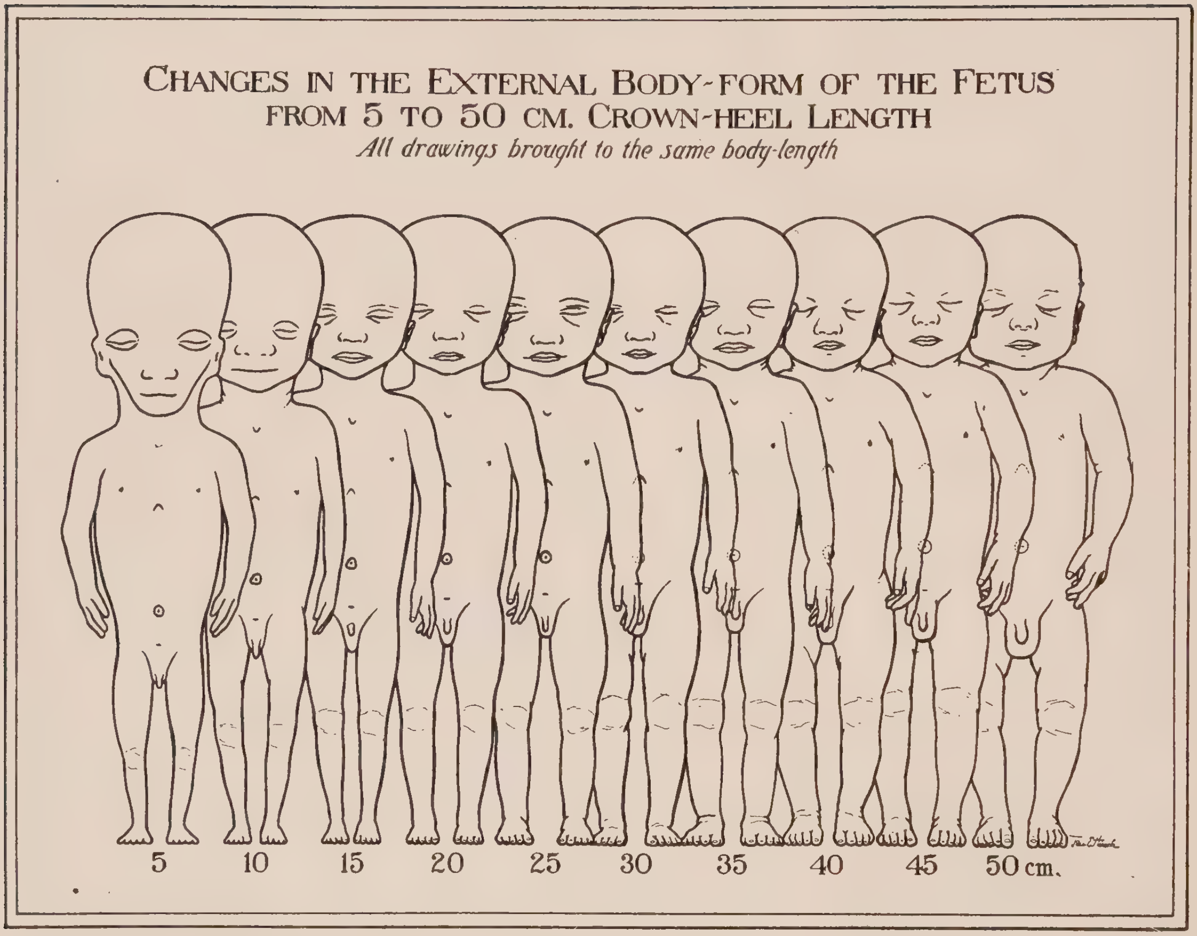
The drawings were made from selected specimens and have been corrected to conform with the calculated dimensions (as determined by the empirical formulae given in the body of this study) at the various intervals of crown-heel length.

FIGURE 71


CHANGES IN THE EXTERNAL BODY-FORM OF THE FETUS FROM 3 TO 10 LUNAR MONTHS
¼ Natural Size
3
4
5
6
7
8
9
10 mo.

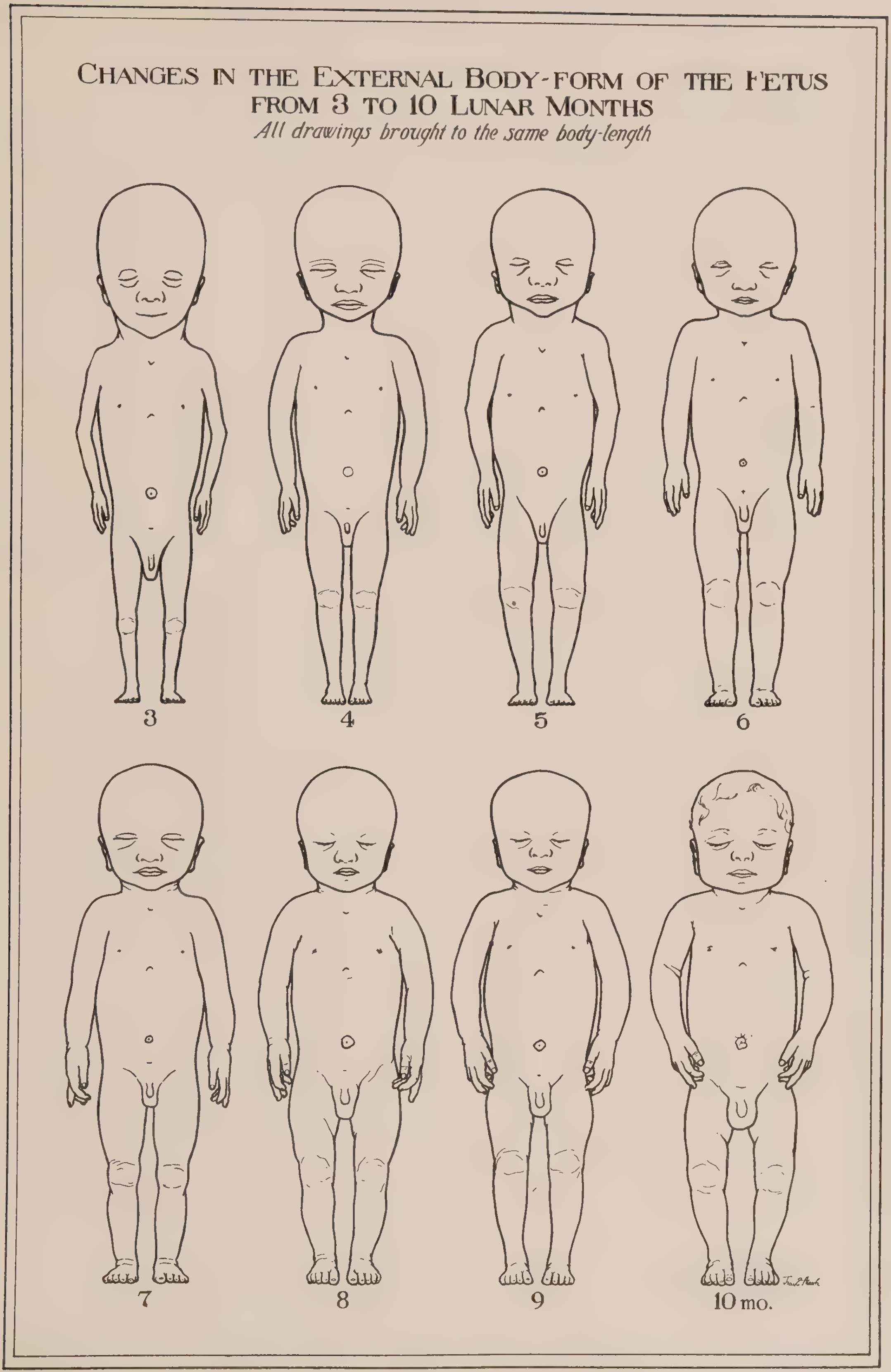
The drawings were made by the method described in connection with figure 70.

FIGURE 72


CHANGES IN THE EXTERNAL BODY-FORM OF THE FETUS
FROM 5 TO 50 CM. CROWN-HEEL LENGTH
All drawings brought to the same body-length
5
10
15
20
25
30
35
40
45
50 cm.

The drawings were made by the method described in connection with figure 70.

FIGURE 73



CHANGES IN THE EXTERNAL BODY-FORM OF THE FETUS FROM 3 TO 10 LUNAR MONTHS

All drawings brought to the same body-length

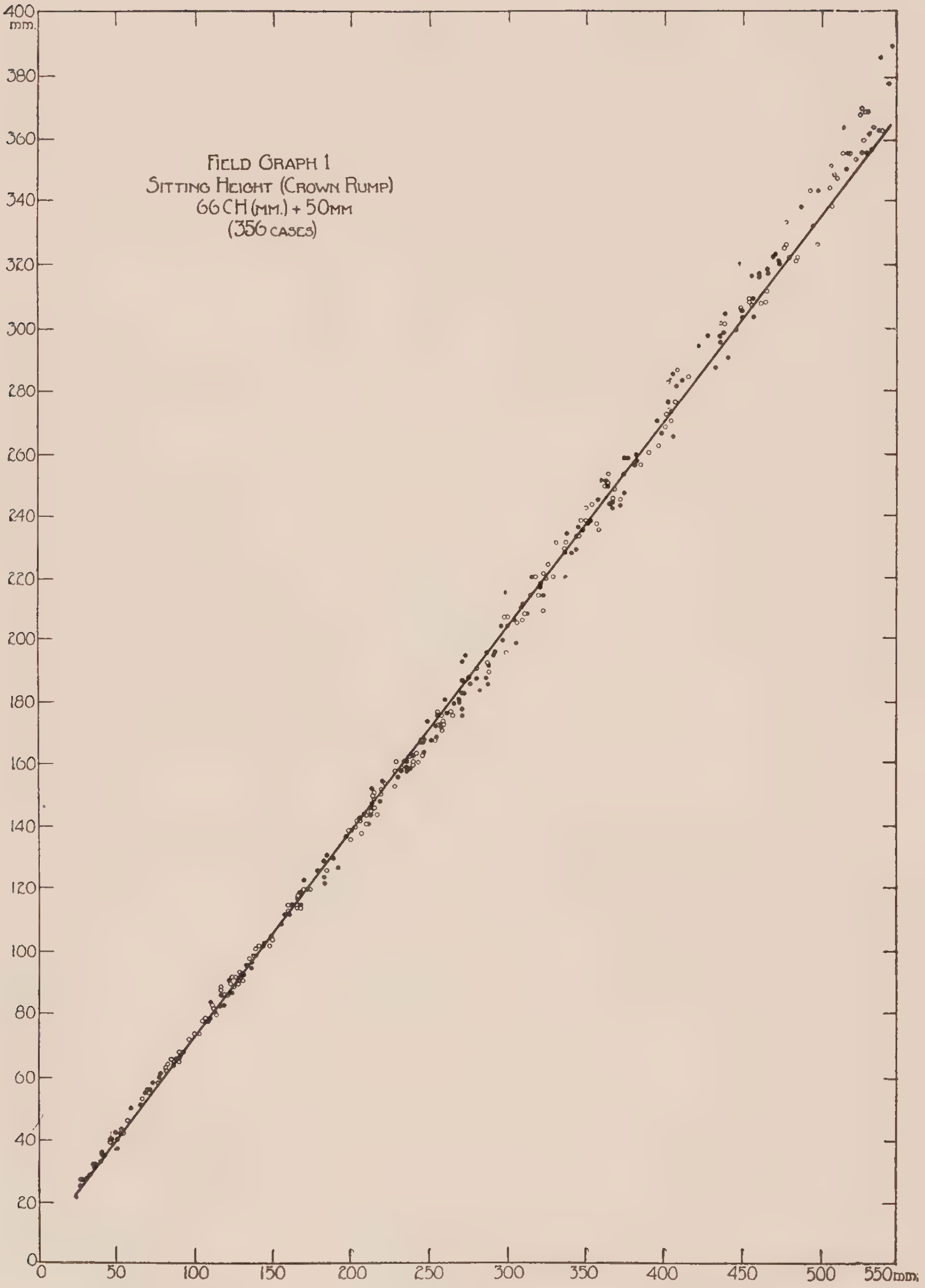
The drawings were made by the method described in connection with figure 70.

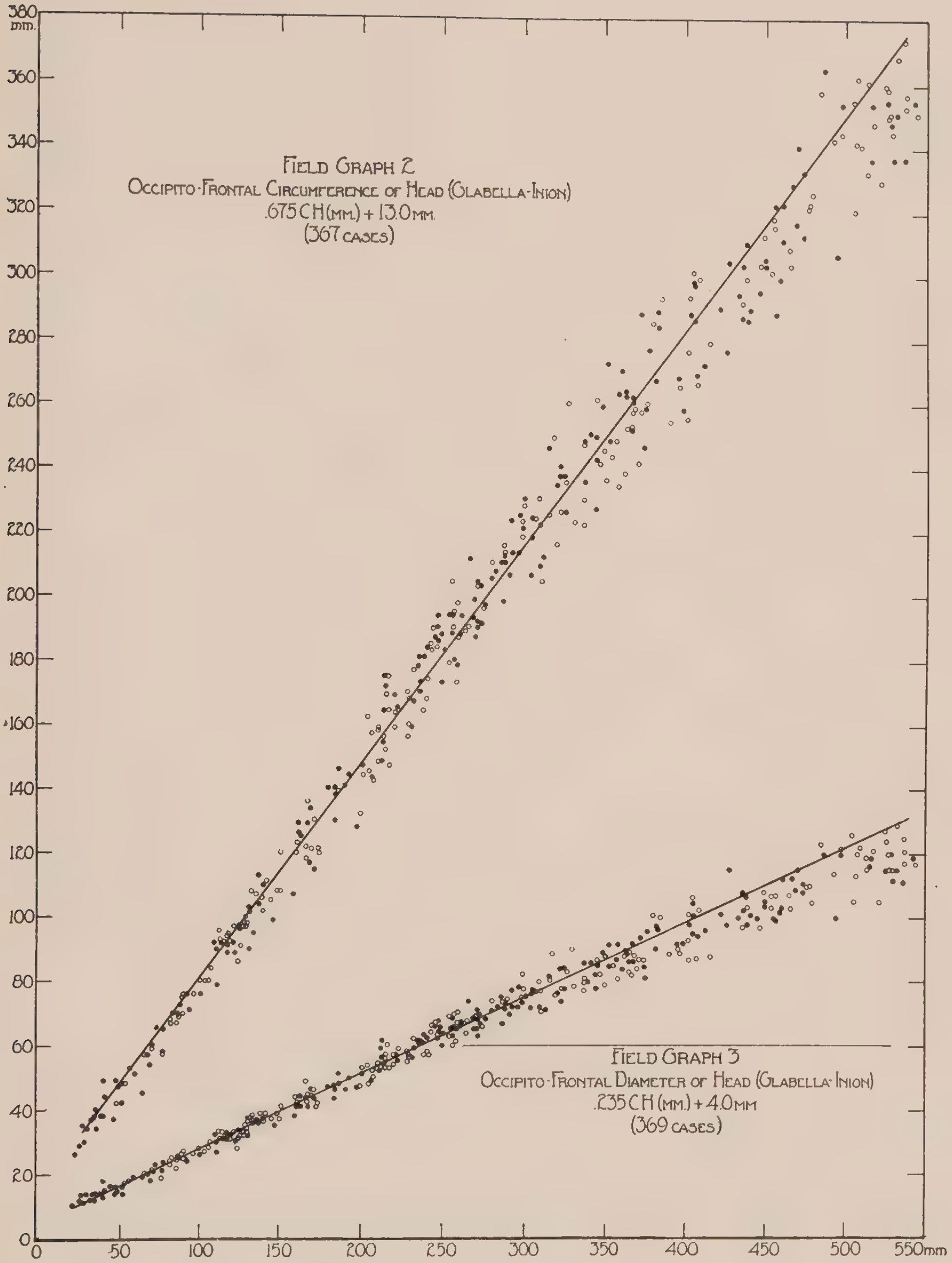
PART XV

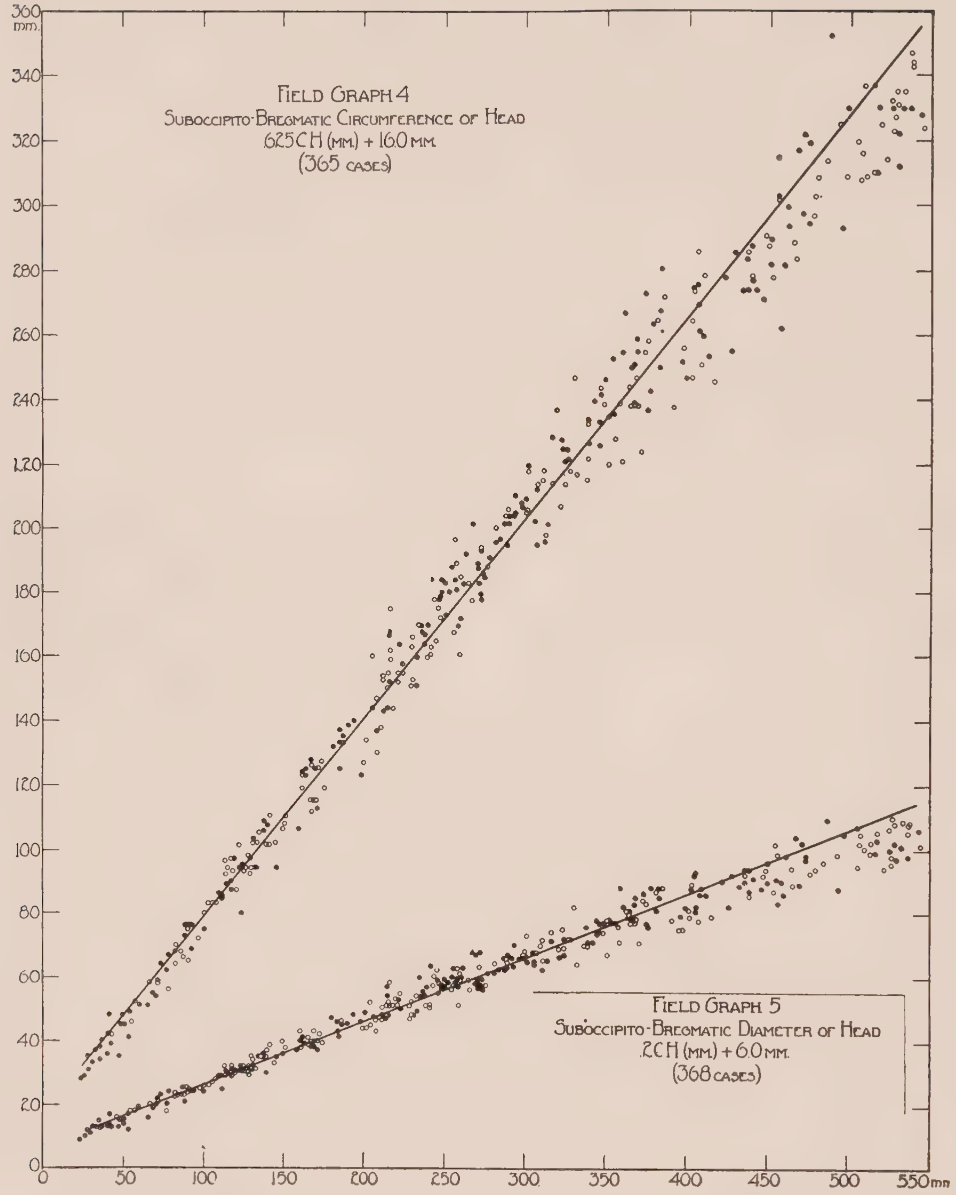
FIELD GRAPHS

In the following graphs the various external dimensions of the body are, in each instance, plotted against the total or crown-heel body-length. Individual cases are represented by dots. Solid dots represent males, circled dots females, and crossed dots specimens of unknown sex. The lines of central tendency are drawn according to the empirical formulae with constants established by the graphic methods described in the text. The graphs are plotted without correction for the effect of artifacts on individual measurements, and the scatters of the symbols for these measurements therefore include all artifactual errors. The curves of central tendency, on the other hand, have been corrected for artifactual effects. Therefore, the fits for measurements between bony points appear more precise than those for dimensions involving soft parts. In estimating the goodness of fit, particularly of the upper segments of these progressions, reference should be made to the general tabular presentation of corrections for artifacts (tables 5 to 8, inclusive) and to the statements on artifacts in the summaries of findings on individual dimensions.

The graphs are arranged in the approximate order of discussion in the text.

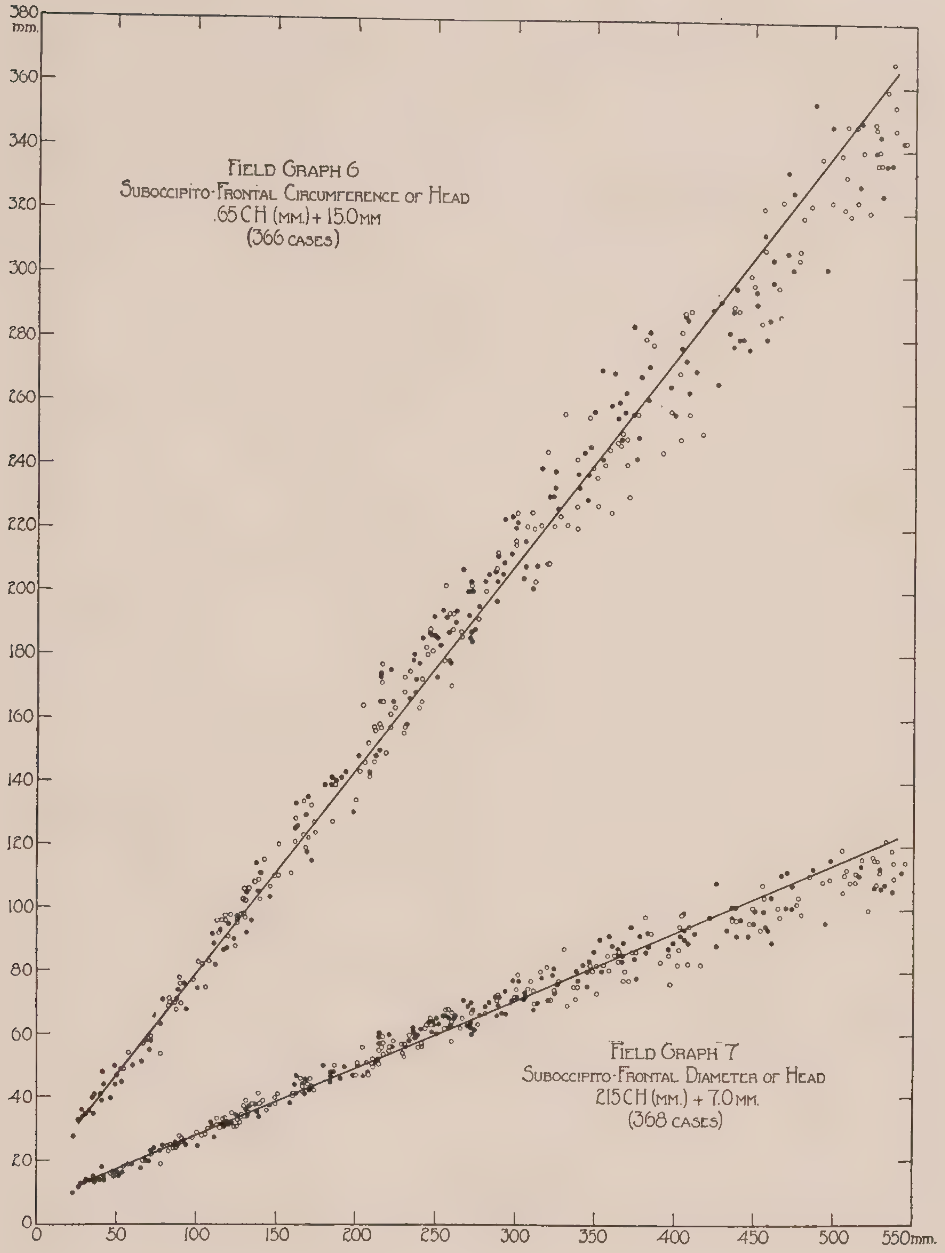

Field Graph 1
Sitting Height (Crown Rump)
.66 CH (mm.) + 50mm
(356 cases)
400 mm.
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550mm.

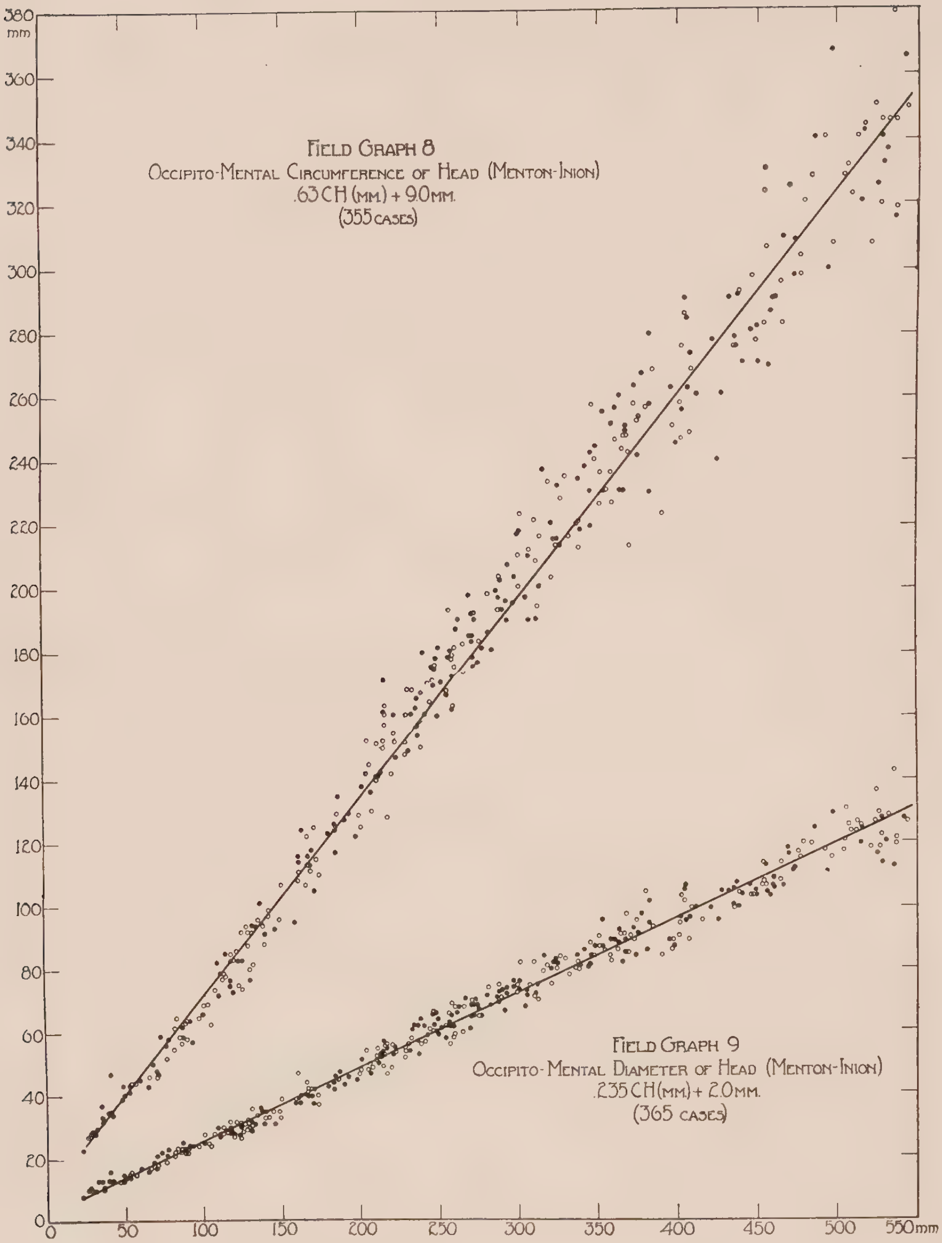

Field Graph 2
Occipito-Frontal Circumference of Head (Glabella-Inion)
.675 CH (mm.) + 13.0 mm.
(367 cases)
Field Graph 3
Occipito-Frontal Diameter of Head (Glabella-Inion)
.235 CH (mm.) + 4.0 mm
(369 cases)
380 mm.
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550mm

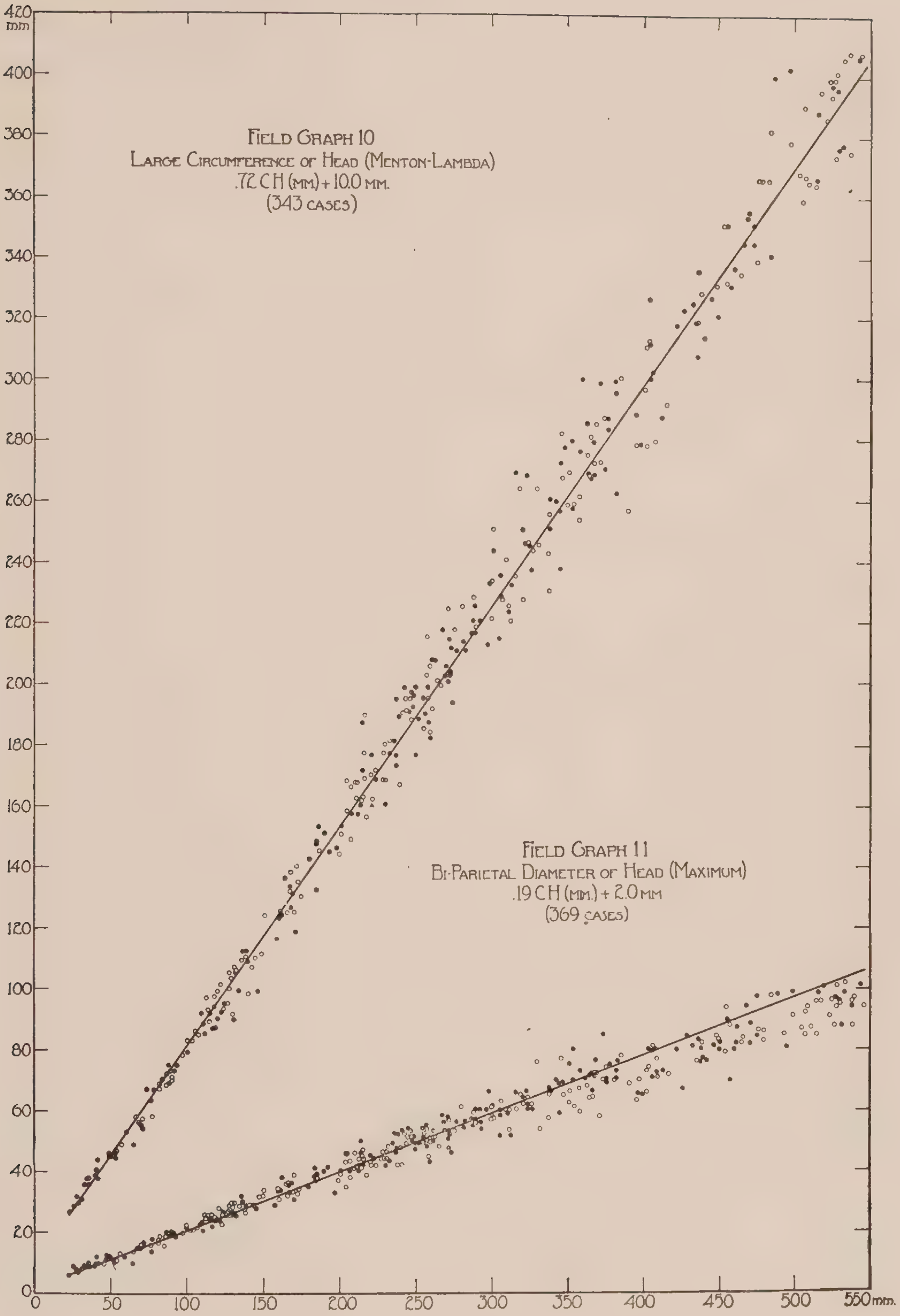


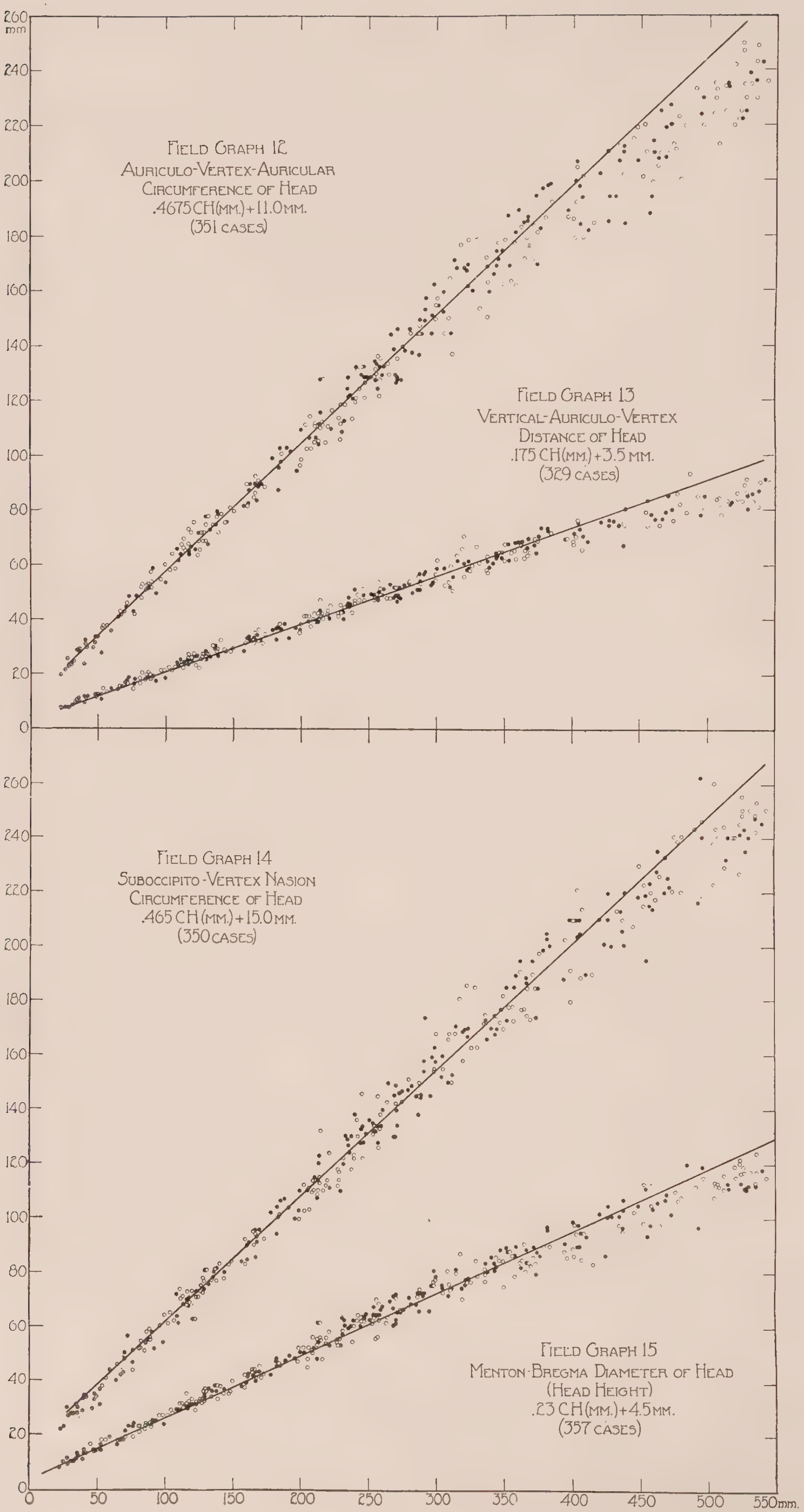
Field Graph 4
Suboccipito-Bregmatic Circumference of Head
.625 CH (mm.) + 16.0 mm.
(365 cases)

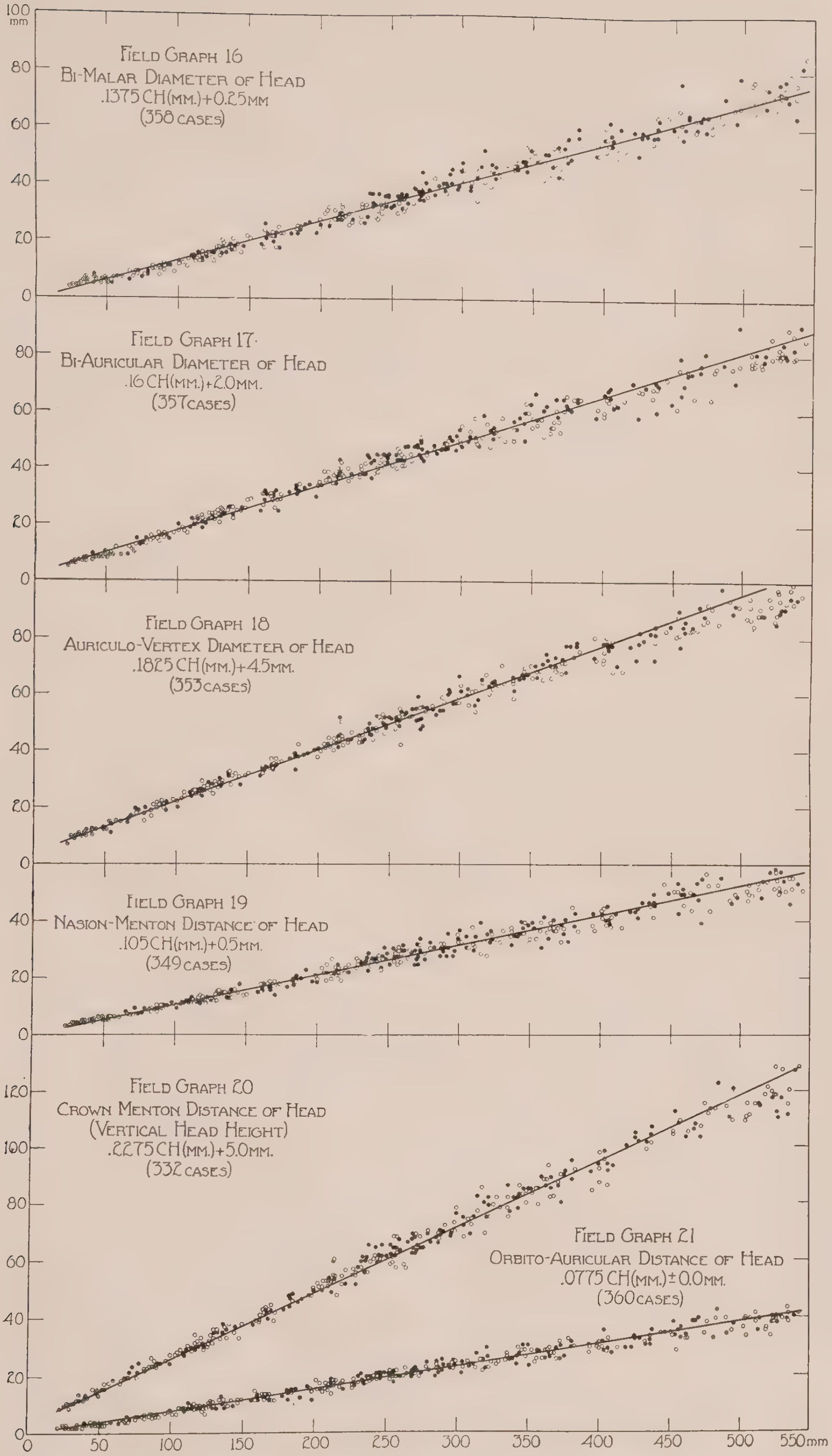
Field Graph 5
Suboccipito-Bregmatic Diameter of Head
.2 CH (mm) + 6.0 mm.
(368 cases)

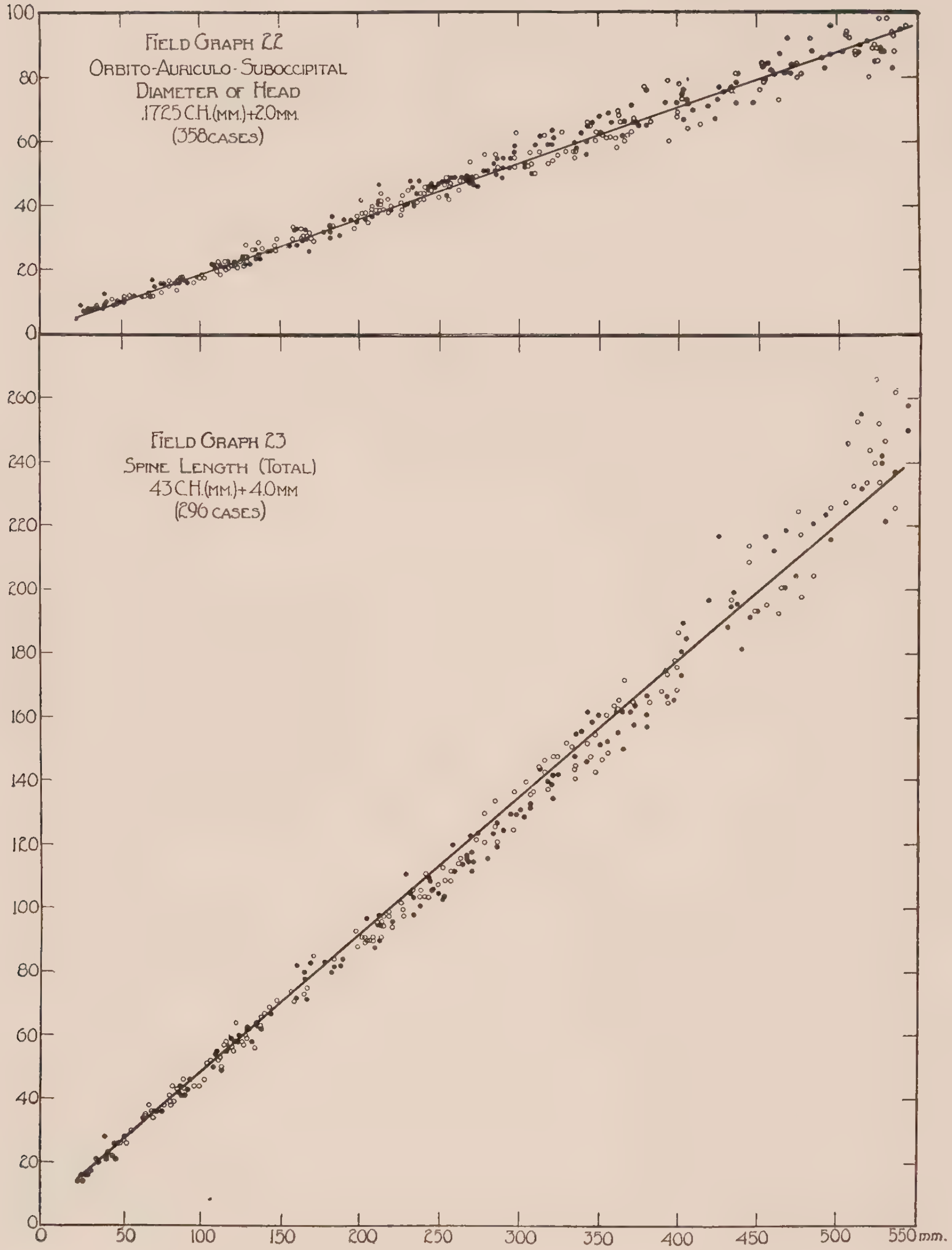

380 mm.
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550mm.
Field Graph 6
Suboccipito-Frontal Circumference of Head
.65 C H (mm.) + 15.0 mm
(366 cases)
Field Graph 7
Suboccipito-Frontal Diameter of Head
215 C H (mm.) + 7.0 mm.
(368 cases)

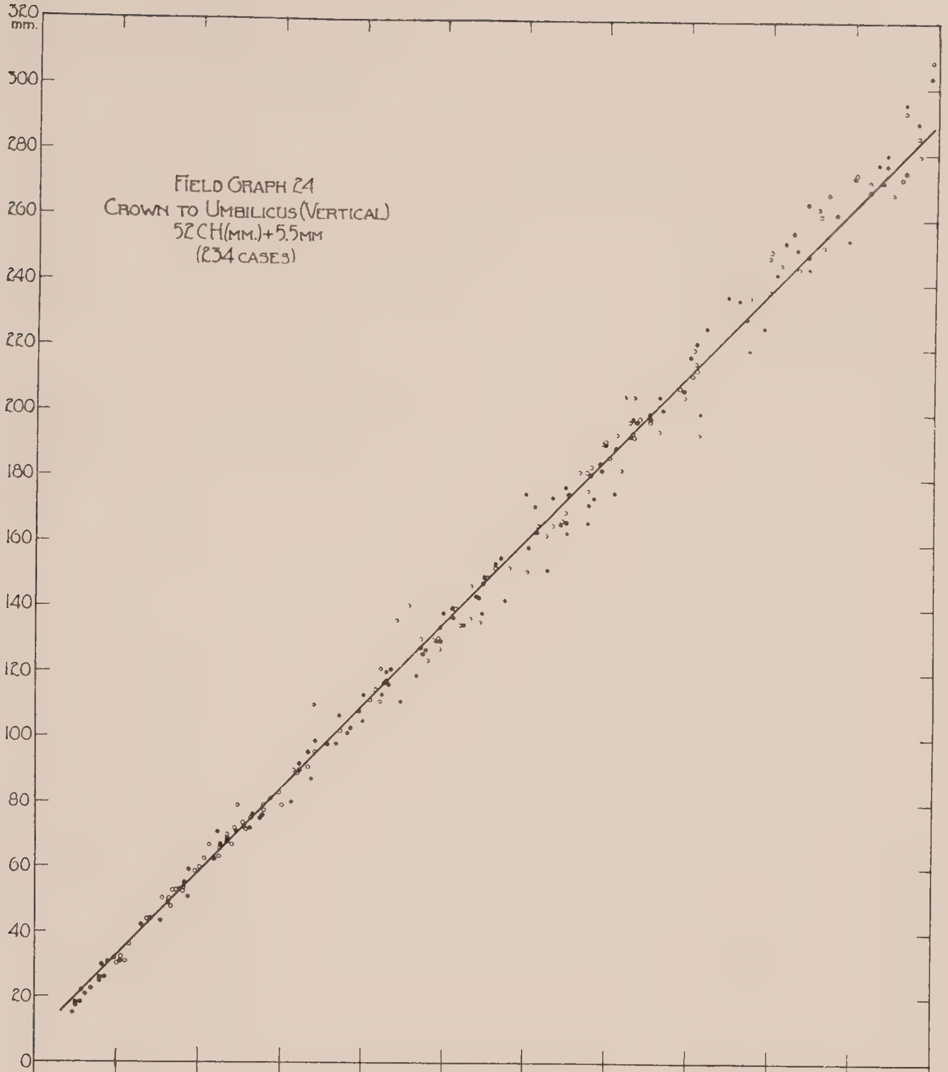

Field Graph 8
Occipito-Mental Circumference of Head (Menton-Inion)
.63 C H (mm.) + 9.0 mm.
(355 cases)
Field Graph 9
Occipito-Mental Diameter of Head (Menton-Inion)
.235 C H (mm.) + 2.0 mm.
(365 cases)
380 mm
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550 mm


420 mm.
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
FIELD GRAPH 10
LARGE CIRCUMFERENCE OF HEAD (MENTON-LAMBDA)
.72 C H (MM.) + 10.0 MM.
(343 CASES)
FIELD GRAPH 11
BI-PARIETAL DIAMETER OF HEAD (MAXIMUM)
.19 C H (MM.) + 2.0 MM
(369 CASES)
0
50
100
150
200
250
300
350
400
450
500
550 mm.

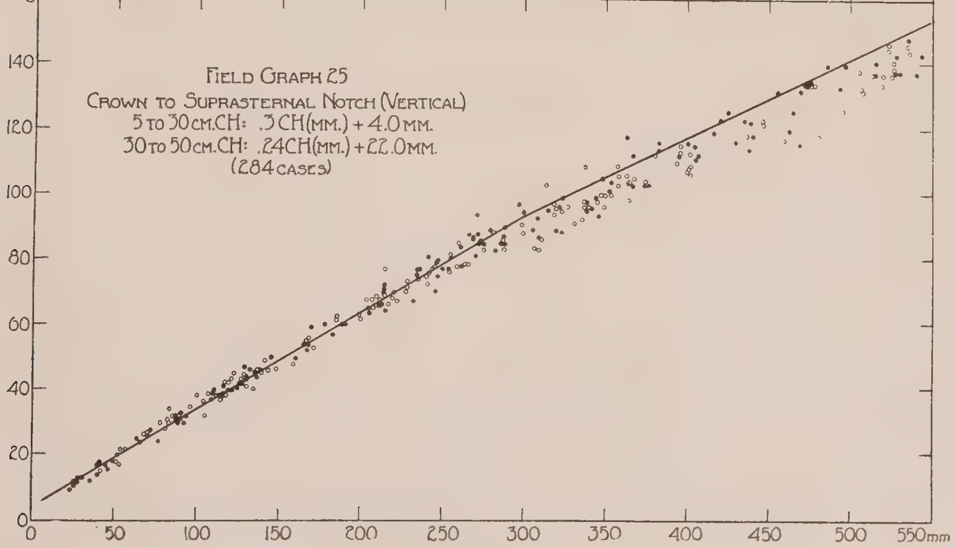

Field Graph 12
Auriculo-Vertex-Auricular
Circumference of Head
.4675 CH(mm.)+11.0mm.
(351 cases)
Field Graph 13
Vertical-Auriculo-Vertex
Distance of Head
.175 CH(mm.)+3.5 mm.
(329 cases)
Field Graph 14
Suboccipito-Vertex Nasion
Circumference of Head
.465 CH (mm.)+15.0 mm.
(350 cases)
Field Graph 15
Menton-Bregma Diameter of Head
(Head Height)
.23 CH(mm.)+4.5 mm.
(357 cases)
260 mm
240
220
200
180
160
140
120
100
80
60
40
20
0
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550mm.


100 mm
80
60
40
20
0
Field Graph 16
Bi-Malar Diameter of Head
.1375 CH(mm.)+0.25mm
(358 cases)
80
60
40
20
0
Field Graph 17
Bi-Auricular Diameter of Head
.16 CH(mm.)+2.0mm.
(357 cases)
80
60
40
20
0
Field Graph 18
Auriculo-Vertex Diameter of Head
.1825 CH(mm.)+4.5mm.
(353 cases)
40
20
0
Field Graph 19
Nasion-Menton Distance of Head
.105 CH(mm.)+0.5mm.
(349 cases)
120
100
80
60
40
20
0
Field Graph 20
Crown Menton Distance of Head
(Vertical Head Height)
.2275 CH(mm.)+5.0mm.
(332 cases)
Field Graph 21
Orbito-Auricular Distance of Head
.0775 CH(mm.)±0.0mm.
(360 cases)
0
50
100
150
200
250
300
350
400
450
500
550mm

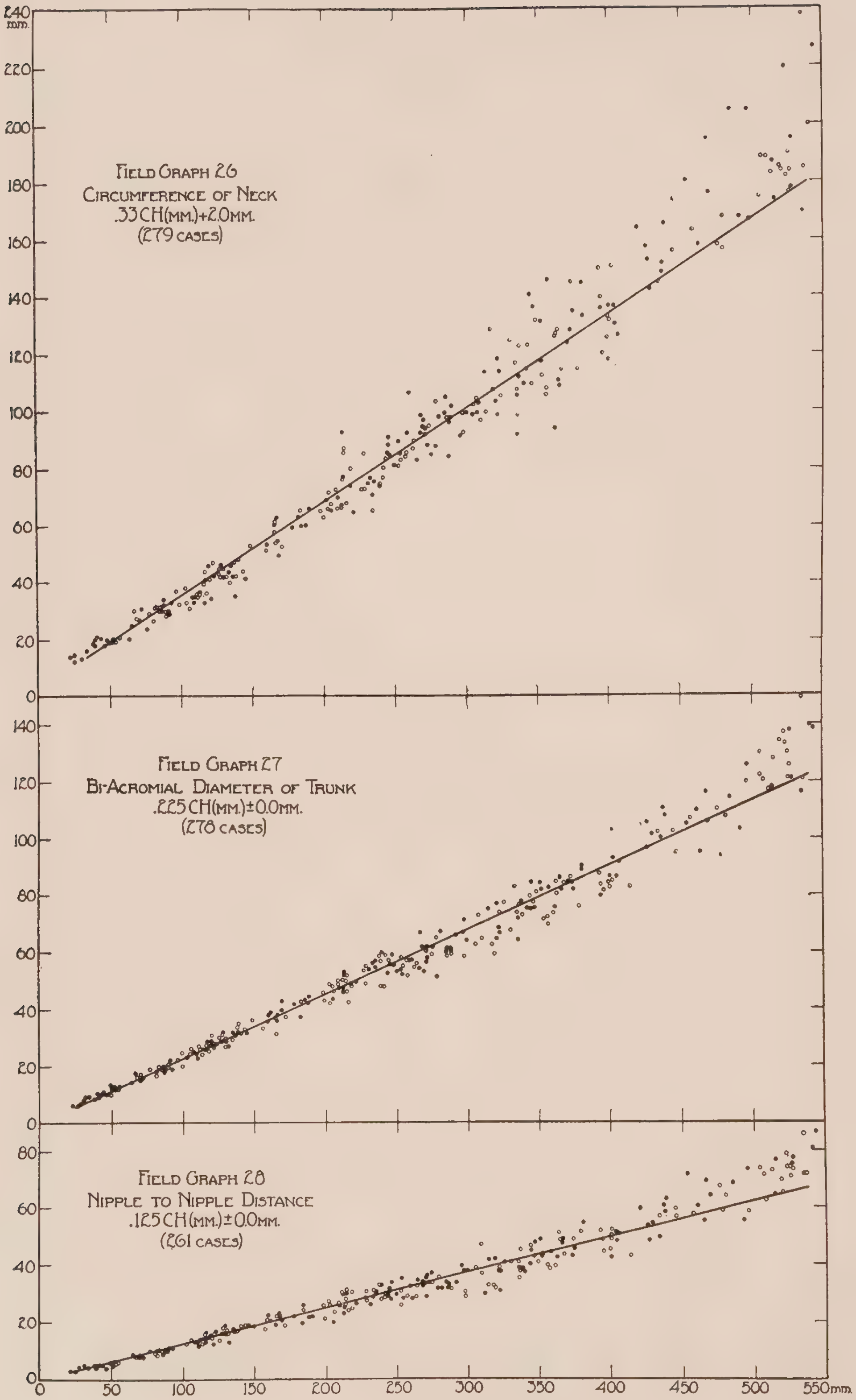

FIELD GRAPH 22
ORBITO-AURICULO-SUBOCCIPITAL
DIAMETER OF HEAD
.1725 C.H.(MM.)+2.0MM.
(358 CASES)
100
80
60
40
20
0
FIELD GRAPH 23
SPINE LENGTH (TOTAL)
.43 C.H.(MM.)+4.0MM
(296 CASES)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550 mm.

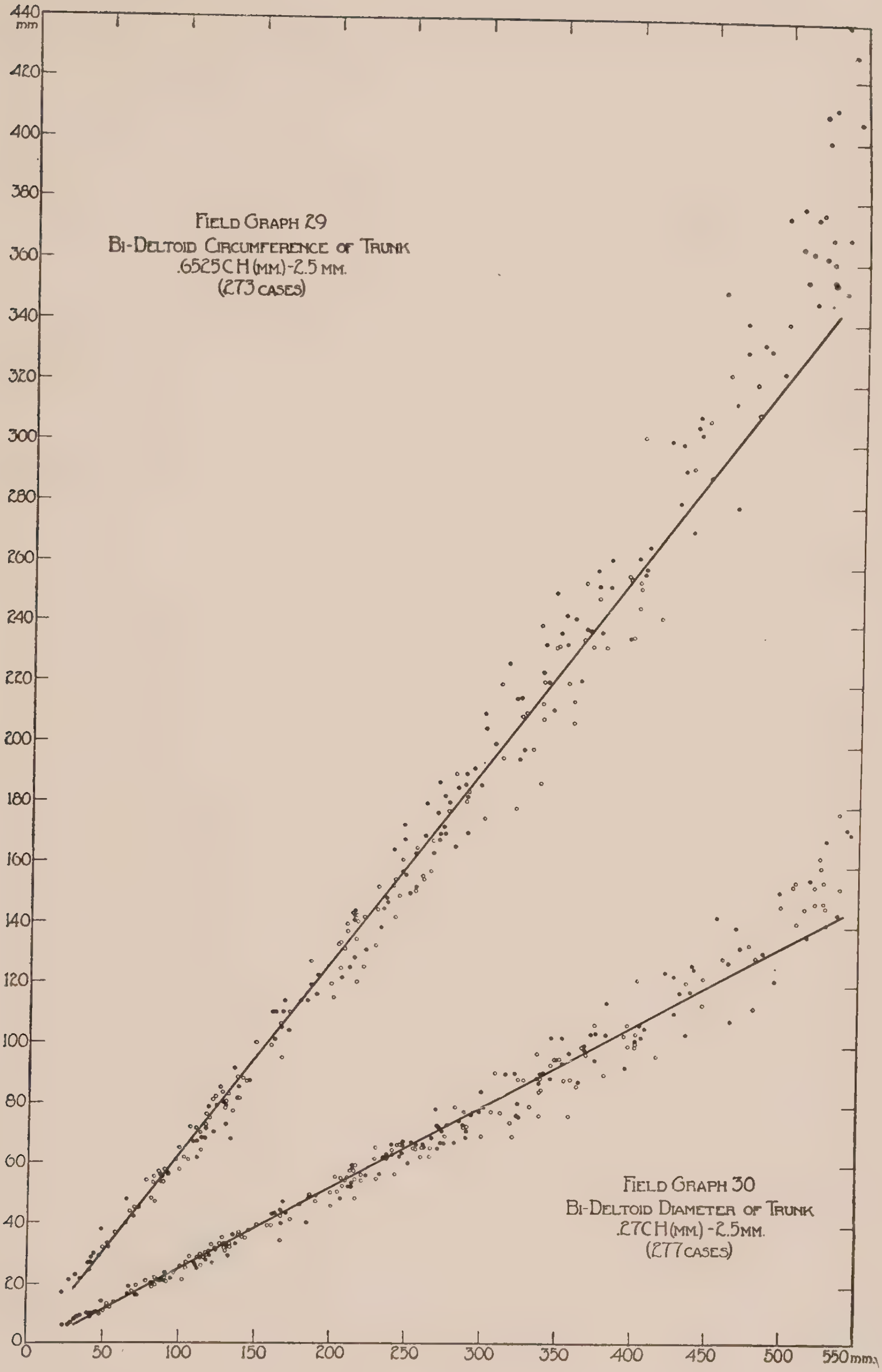


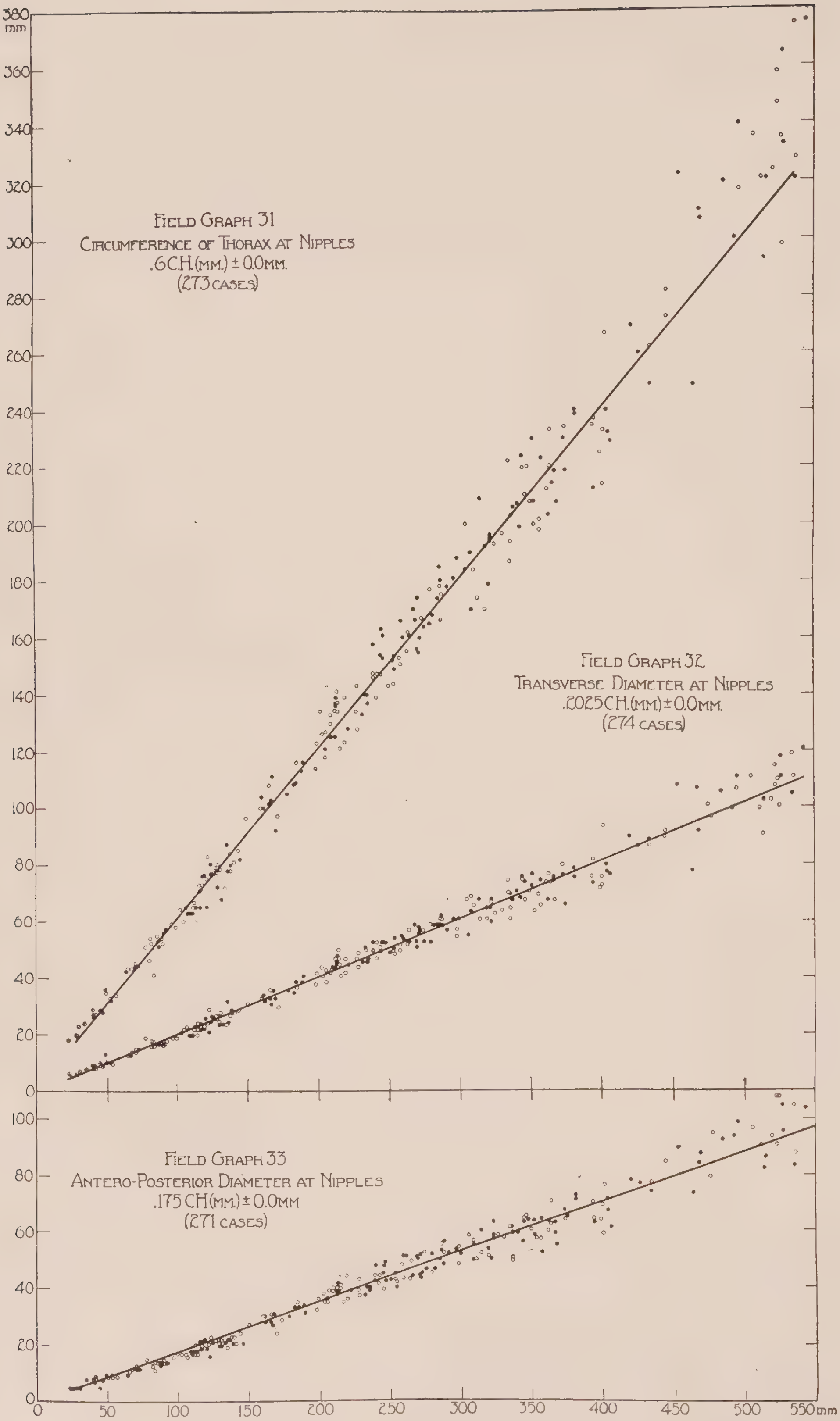
FIELD GRAPH 24
CROWN TO UMBILICUS (VERTICAL)
.52 CH (MM.) + 5.5 MM
(234 CASES)

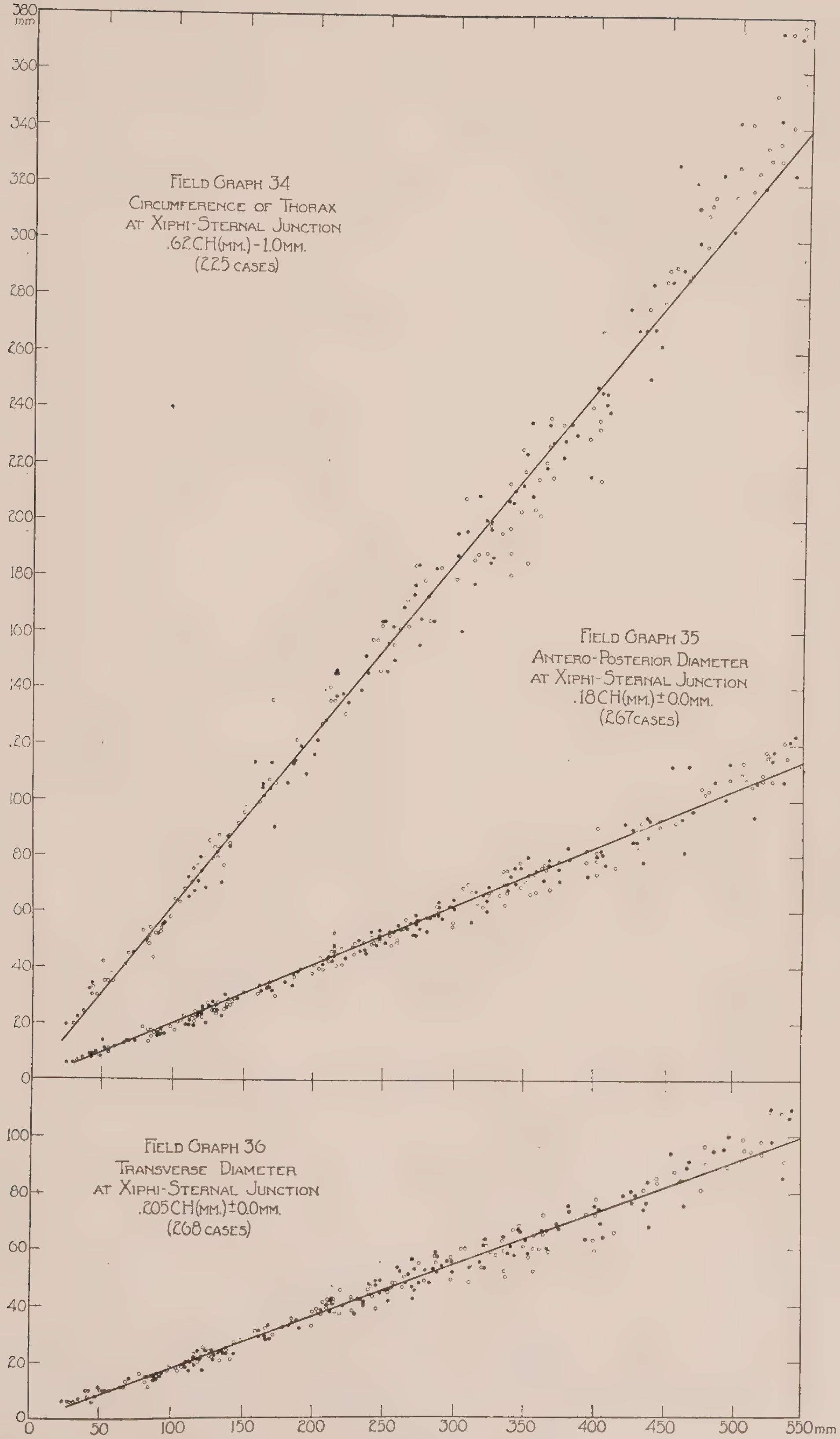


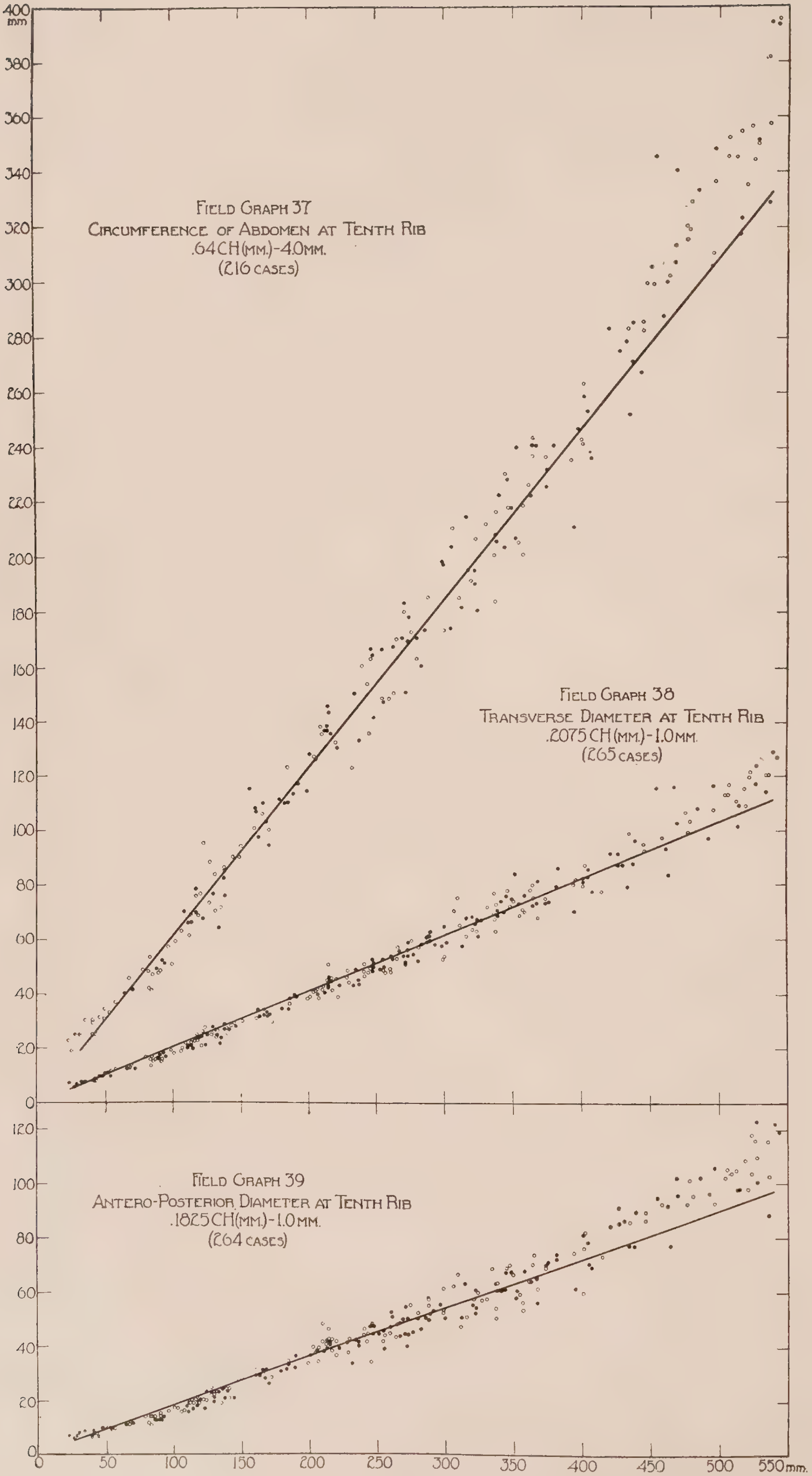
FIELD GRAPH 25
CROWN TO SUPRASTERNAL NOTCH (VERTICAL)
5 TO 30 CM. CH: .3 CH (MM.) + 4.0 MM.
30 TO 50 CM. CH: .24 CH (MM.) + 22.0 MM.
(284 CASES)

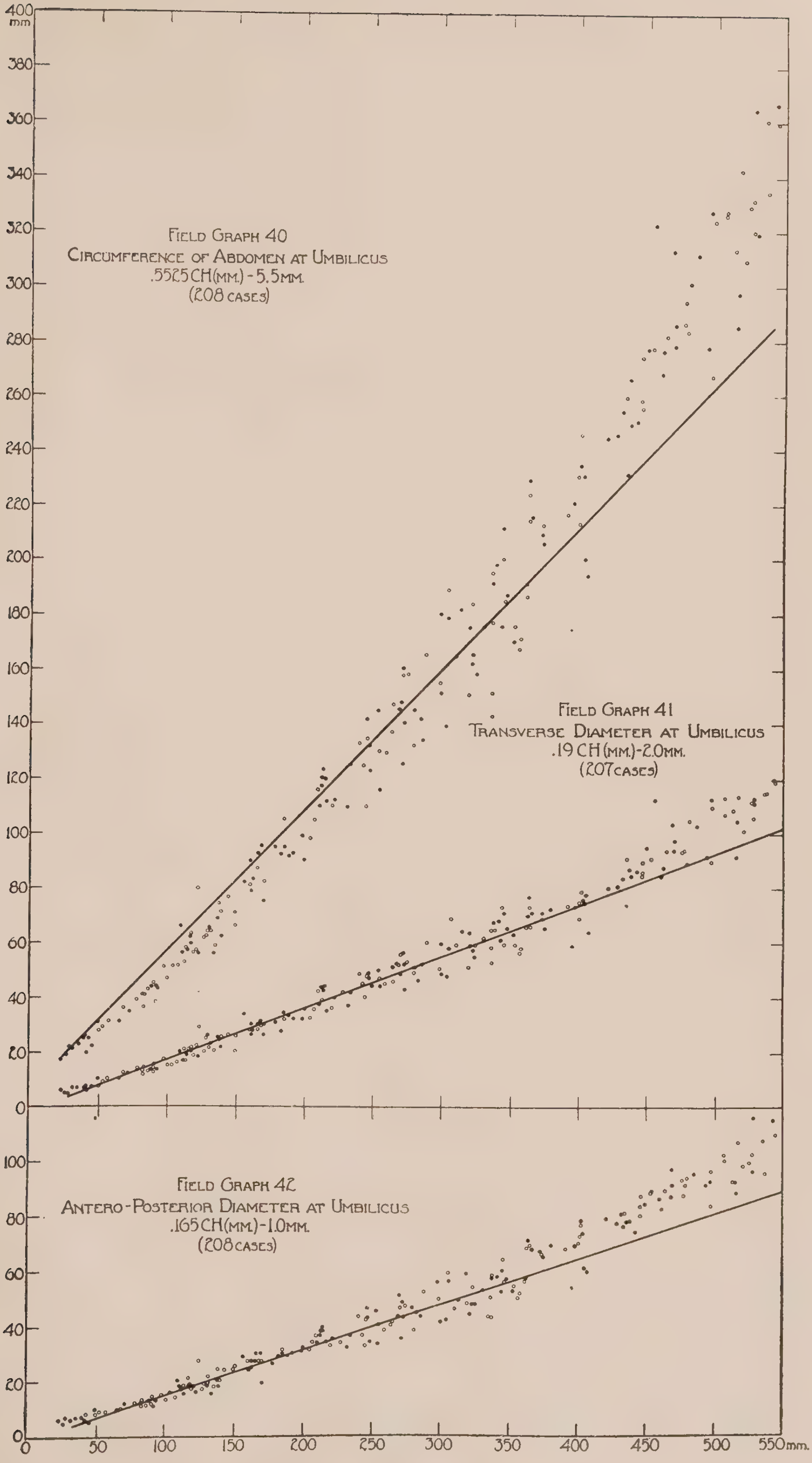

240 mm.
220
200
180
160
140
120
100
80
60
40
20
0
Field Graph 26
Circumference of Neck
.33 CH(mm.)+2.0mm.
(279 cases)
140
120
100
80
60
40
20
0
Field Graph 27
Bi-Acromial Diameter of Trunk
.225 CH(mm.)±0.0mm.
(278 cases)
80
60
40
20
0
Field Graph 28
Nipple to Nipple Distance
.125 CH(mm.)±0.0mm.
(261 cases)
0
50
100
150
200
250
300
350
400
450
500
550mm.

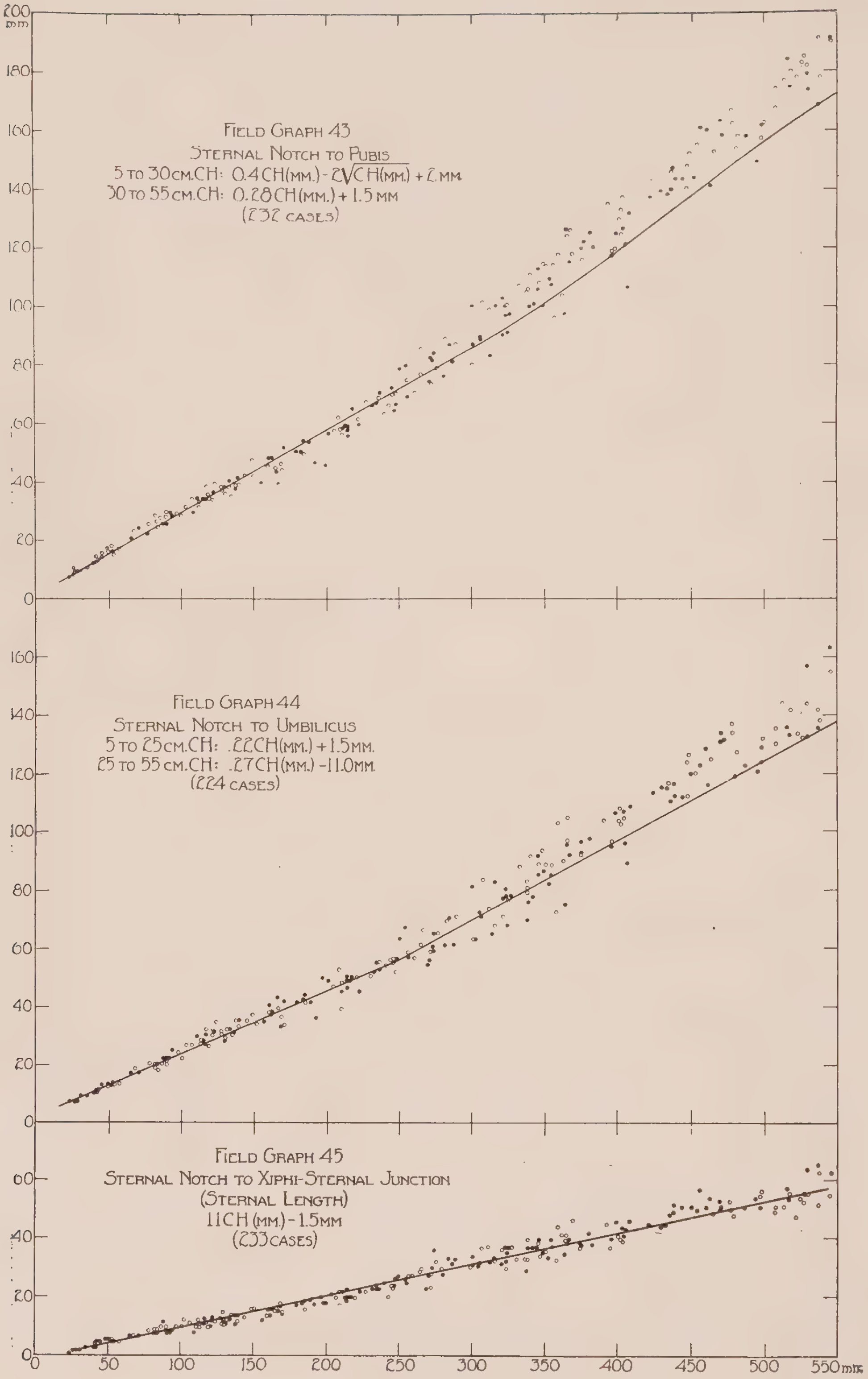

Field Graph 29
Bi-Deltoid Circumference of Trunk
.6525 C H (mm.) - 2.5 mm.
(273 cases)
Field Graph 30
Bi-Deltoid Diameter of Trunk
.27 C H (mm.) - 2.5 mm.
(277 cases)
440 mm
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550 mm.


FIELD GRAPH 31
CIRCUMFERENCE OF THORAX AT NIPPLES
.6C.H.(MM.) ± 0.0MM.
(273 CASES)
FIELD GRAPH 32
TRANSVERSE DIAMETER AT NIPPLES
.2025 C.H.(MM.) ± 0.0MM.
(274 CASES)
FIELD GRAPH 33
ANTERO-POSTERIOR DIAMETER AT NIPPLES
.175 C.H.(MM.) ± 0.0MM
(271 CASES)
380 mm
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550 mm


Field Graph 34
Circumference of Thorax
at Xiphi-Sternal Junction
.62 CH (mm.) - 1.0 mm.
(225 cases)
Field Graph 35
Antero-Posterior Diameter
at Xiphi-Sternal Junction
.18 CH (mm.) ± 0.0 mm.
(267 cases)
Field Graph 36
Transverse Diameter
at Xiphi-Sternal Junction
.205 CH (mm.) ± 0.0 mm.
(268 cases)
380 mm
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550 mm


Field Graph 37
Circumference of Abdomen at Tenth Rib
.64 CH (mm.) - 4.0 mm.
(216 cases)
Field Graph 38
Transverse Diameter at Tenth Rib
.2075 CH (mm.) - 1.0 mm.
(265 cases)
Field Graph 39
Antero-Posterior Diameter at Tenth Rib
.1825 CH (mm.) - 1.0 mm.
(264 cases)
400 mm
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550 mm.

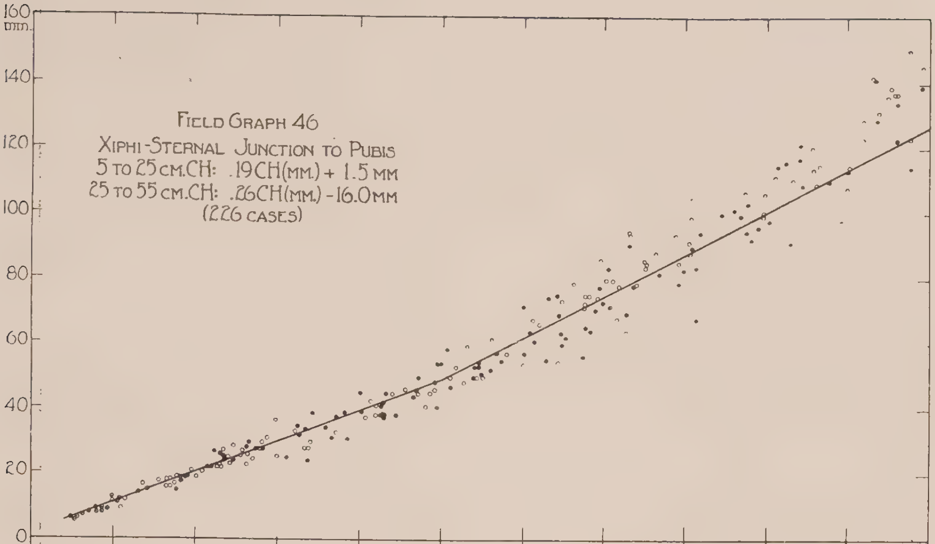

FIELD GRAPH 40
CIRCUMFERENCE OF ABDOMEN AT UMBILICUS
.5525 CH(MM.) - 5.5MM.
(208 CASES)
FIELD GRAPH 41
TRANSVERSE DIAMETER AT UMBILICUS
.19 CH(MM.)-2.0MM.
(207 CASES)
FIELD GRAPH 42
ANTERO-POSTERIOR DIAMETER AT UMBILICUS
.165 CH(MM.)-1.0MM.
(208 CASES)
400 mm
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550mm.



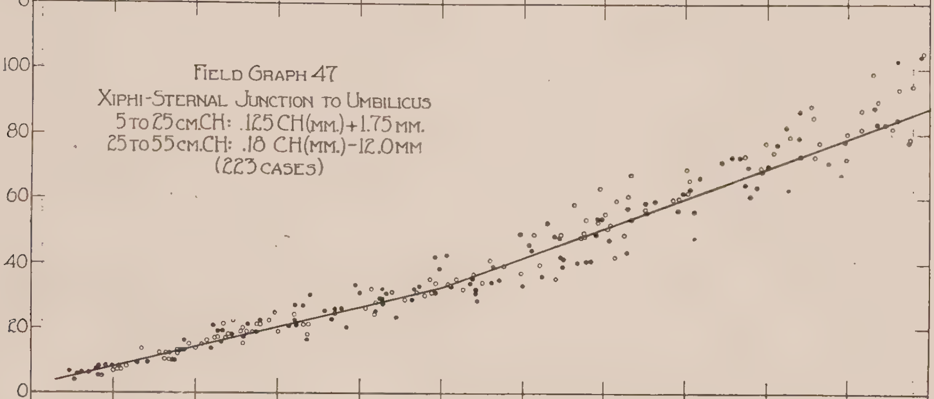
Field Graph 43
Sternal Notch to Pubis
5 to 30 cm. CH: 0.4 CH (mm.) - $2\sqrt{\text{CH (mm.)}}$ + 2 mm.
30 to 55 cm. CH: 0.28 CH (mm.) + 1.5 mm.
(232 cases)

Field Graph 44
Sternal Notch to Umbilicus
5 to 25 cm. CH: .22 CH (mm.) + 1.5 mm.
25 to 55 cm. CH: .27 CH (mm.) - 11.0 mm.
(224 cases)

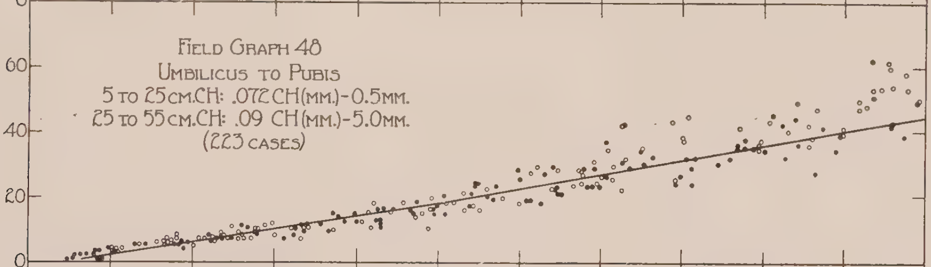
Field Graph 45
Sternal Notch to Xiphi-Sternal Junction
(Sternal Length)
.11 CH (mm.) - 1.5 mm
(233 cases)



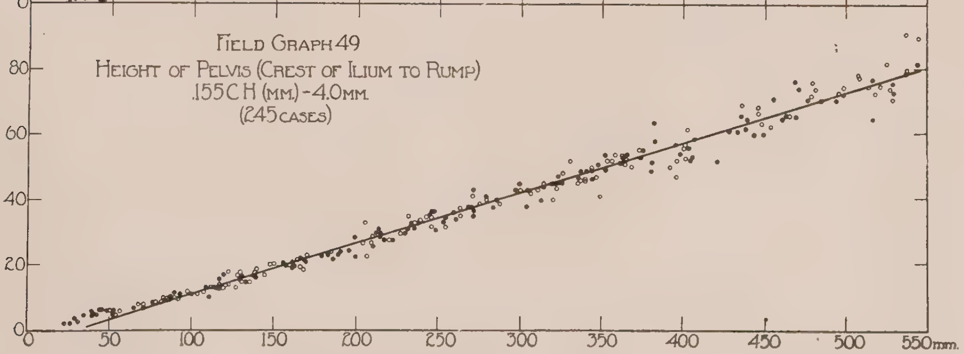
Field Graph 46
Xiphi-Sternal Junction to Pubis
5 to 25 cm.CH: .19CH(mm.) + 1.5 mm
25 to 55 cm.CH: .26CH(mm.) -16.0mm
(226 cases)



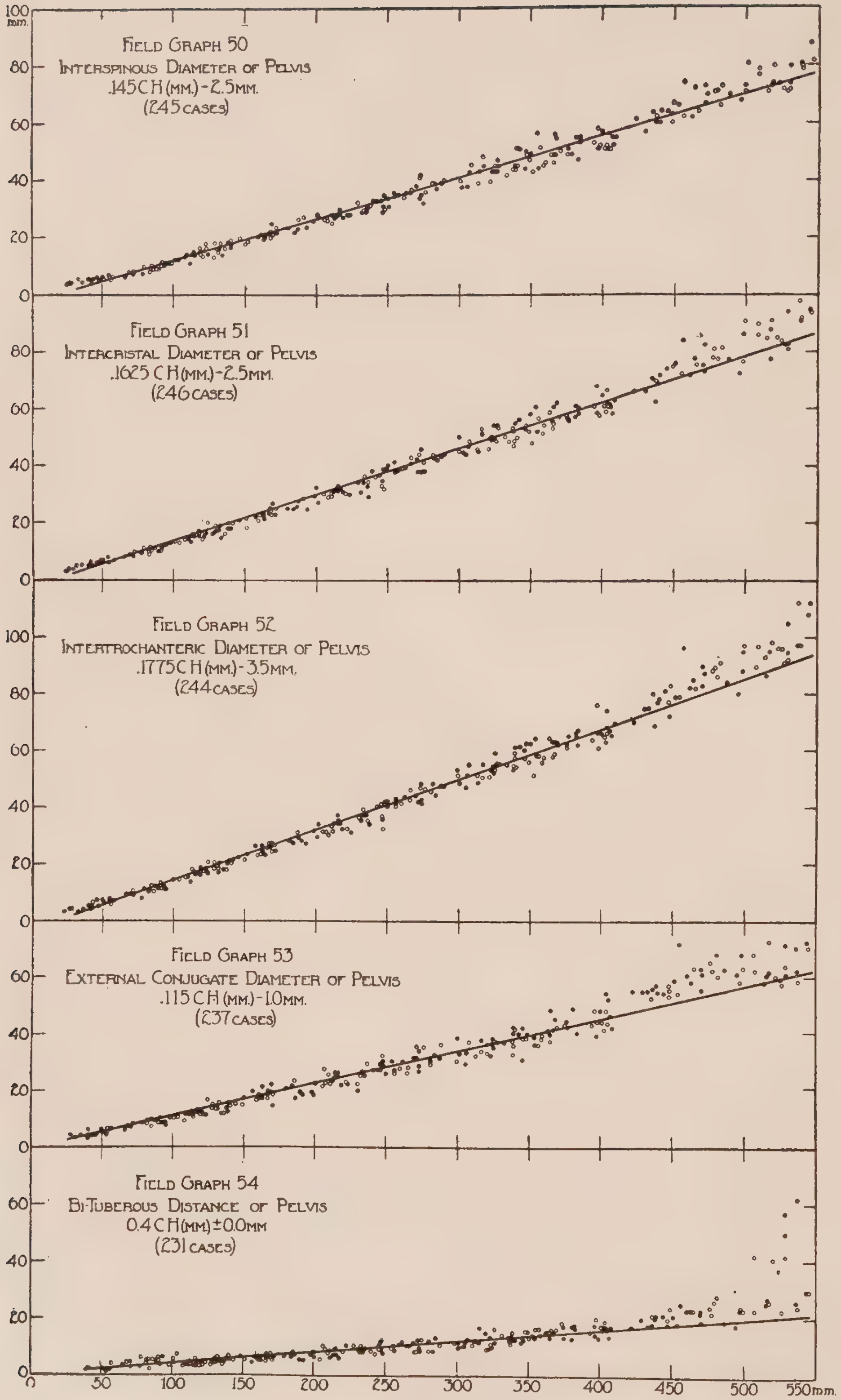
Field Graph 47
Xiphi-Sternal Junction to Umbilicus
5 to 25 cm.CH: .125 CH(mm.)+1.75 mm.
25 to 55 cm.CH: .18 CH(mm.)-12.0mm
(223 cases)

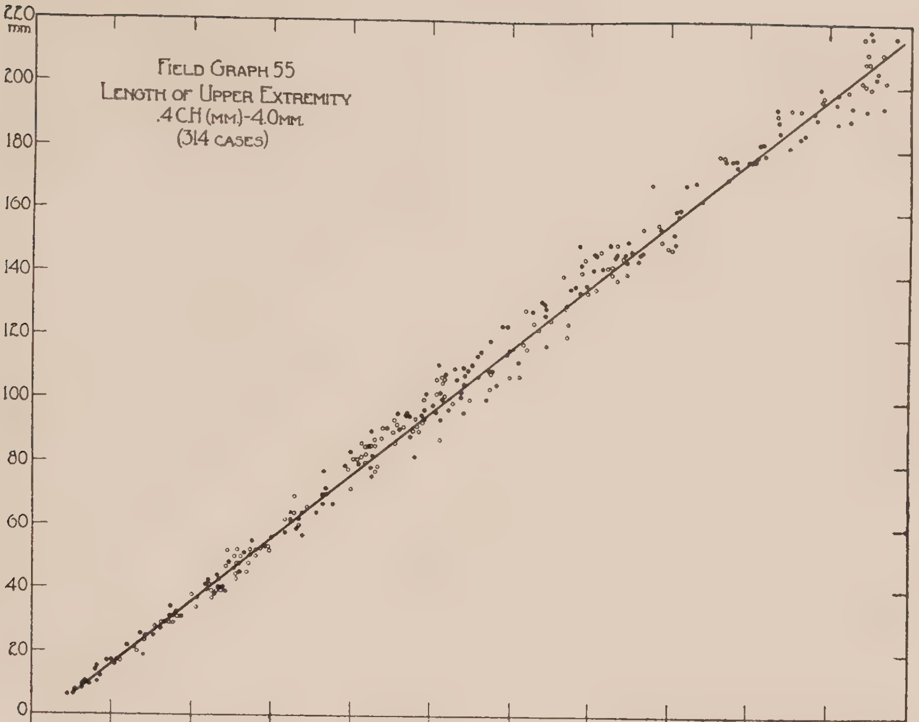


Field Graph 48
Umbilicus to Pubis
5 to 25 cm.CH: .072 CH(mm.)-0.5mm.
25 to 55 cm.CH: .09 CH(mm.)-5.0mm.
(223 cases)

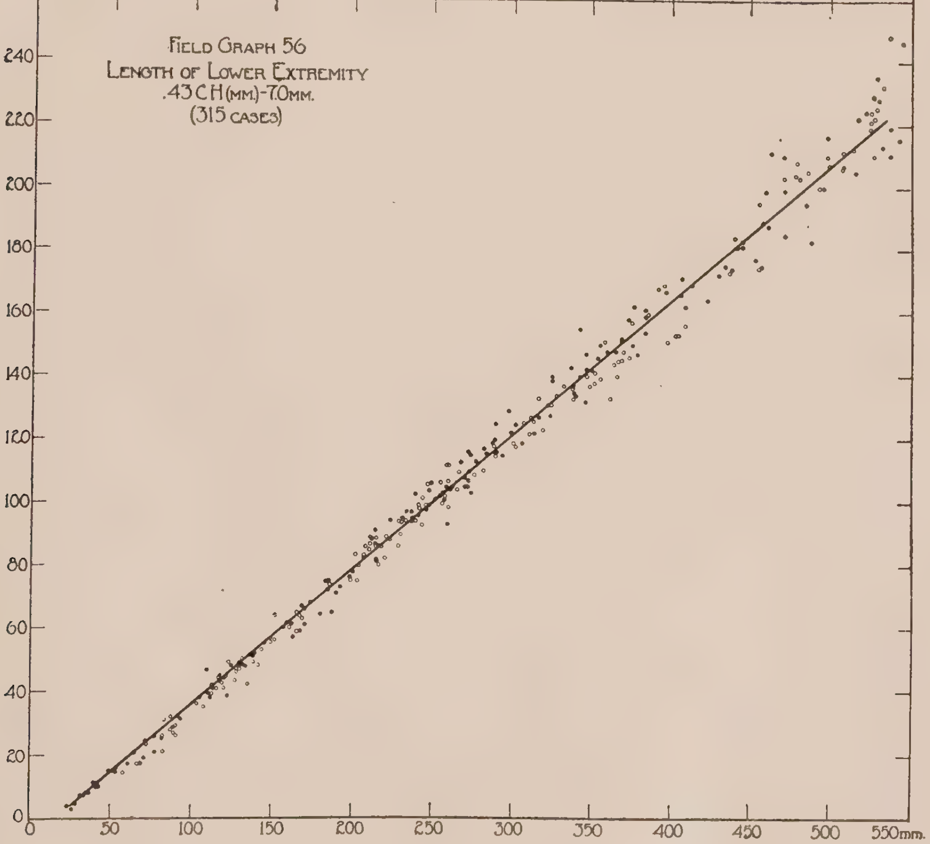


Field Graph 49
Height of Pelvis (Crest of Ilium to Rump)
.155CH (mm.)-4.0mm.
(245 cases)

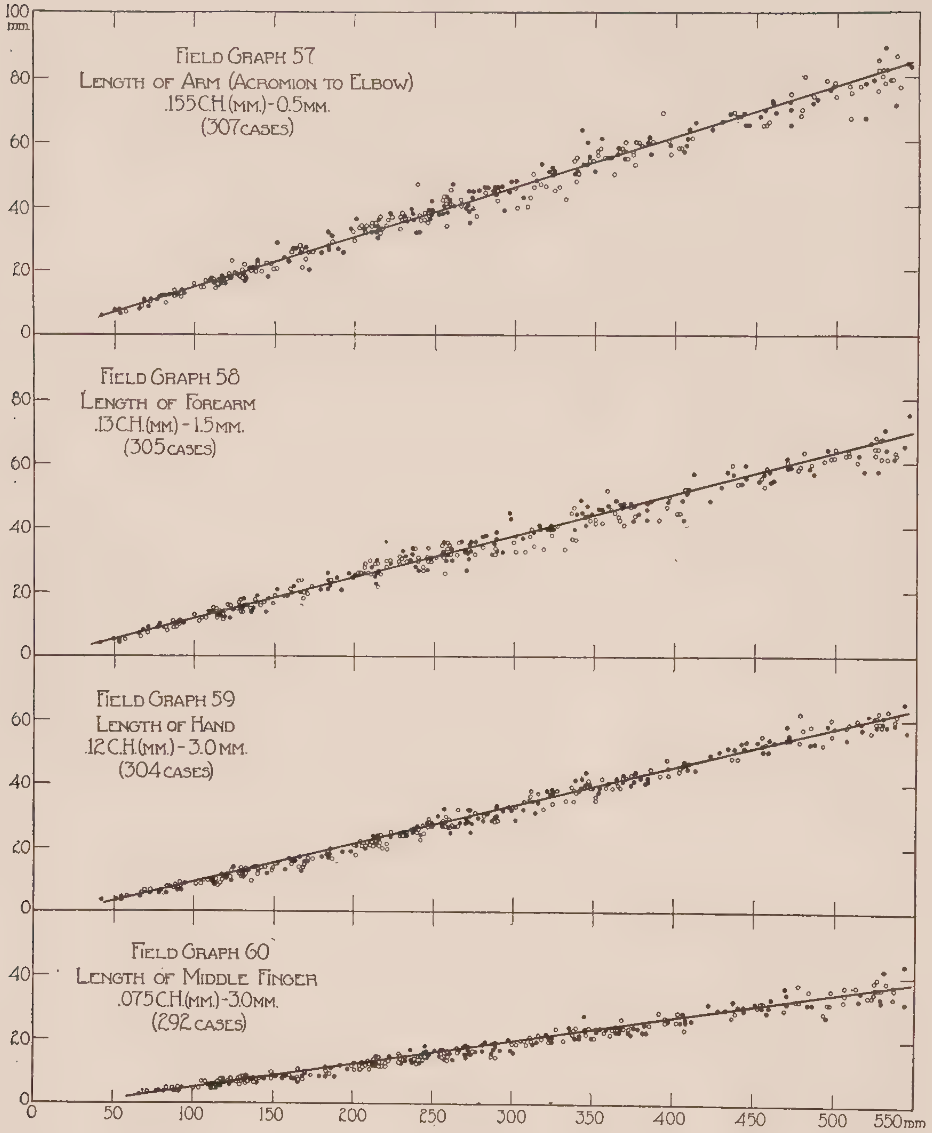

100 mm.
80
60
40
20
0
Field Graph 50
Interspinous Diameter of Pelvis
.145 C H (mm.) - 2.5 mm.
(245 cases)
80
60
40
20
0
Field Graph 51
Intercristal Diameter of Pelvis
.1625 C H (mm.) - 2.5 mm.
(246 cases)
100
80
60
40
20
0
Field Graph 52
Intertrochanteric Diameter of Pelvis
.1775 C H (mm.) - 3.5 mm.
(244 cases)
60
40
20
0
Field Graph 53
External Conjugate Diameter of Pelvis
.115 C H (mm.) - 1.0 mm.
(237 cases)
60
40
20
0
Field Graph 54
Bi-Tuberous Distance of Pelvis
0.4 C H (mm) ± 0.0 mm
(231 cases)
0
50
100
150
200
250
300
350
400
450
500
550 mm.

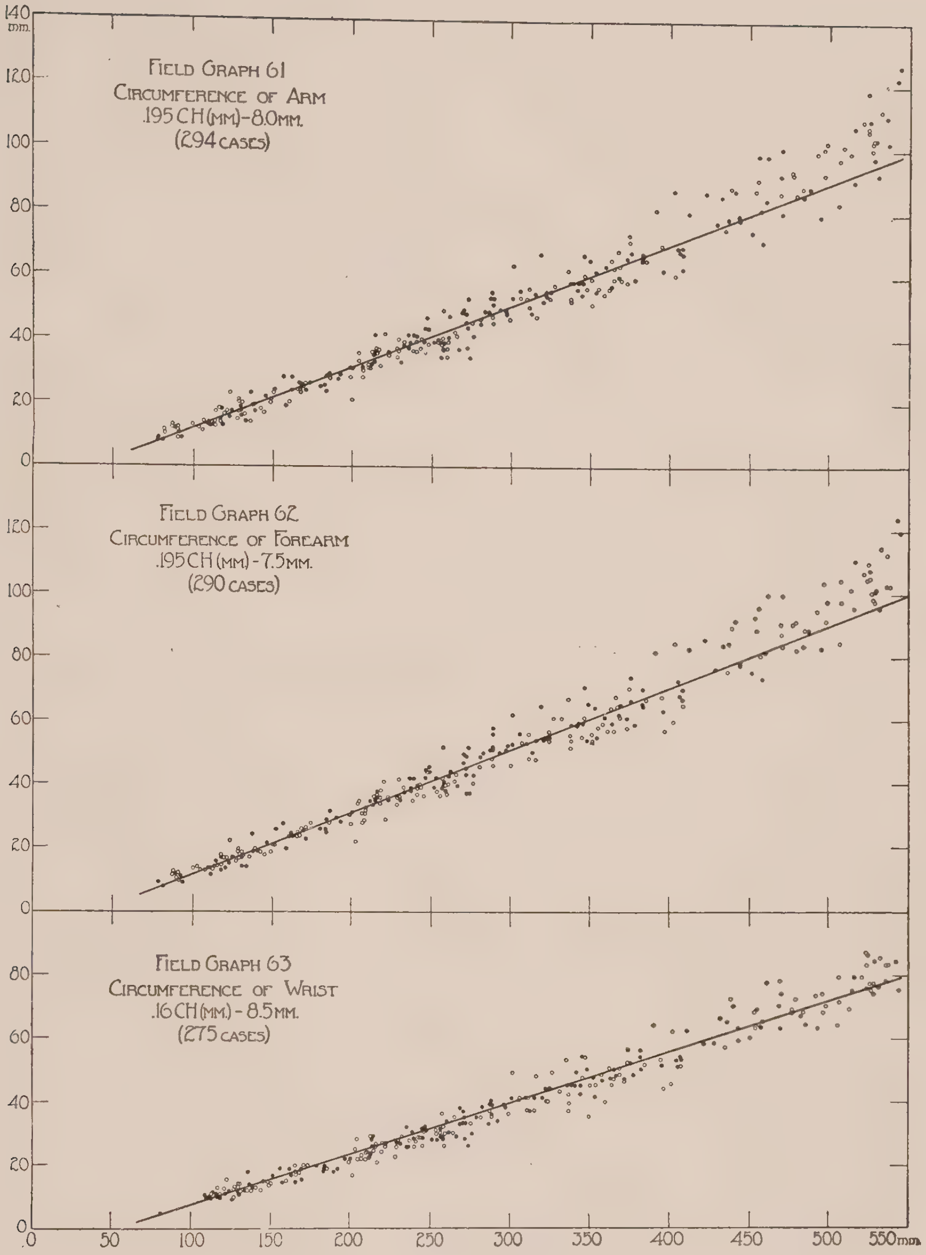


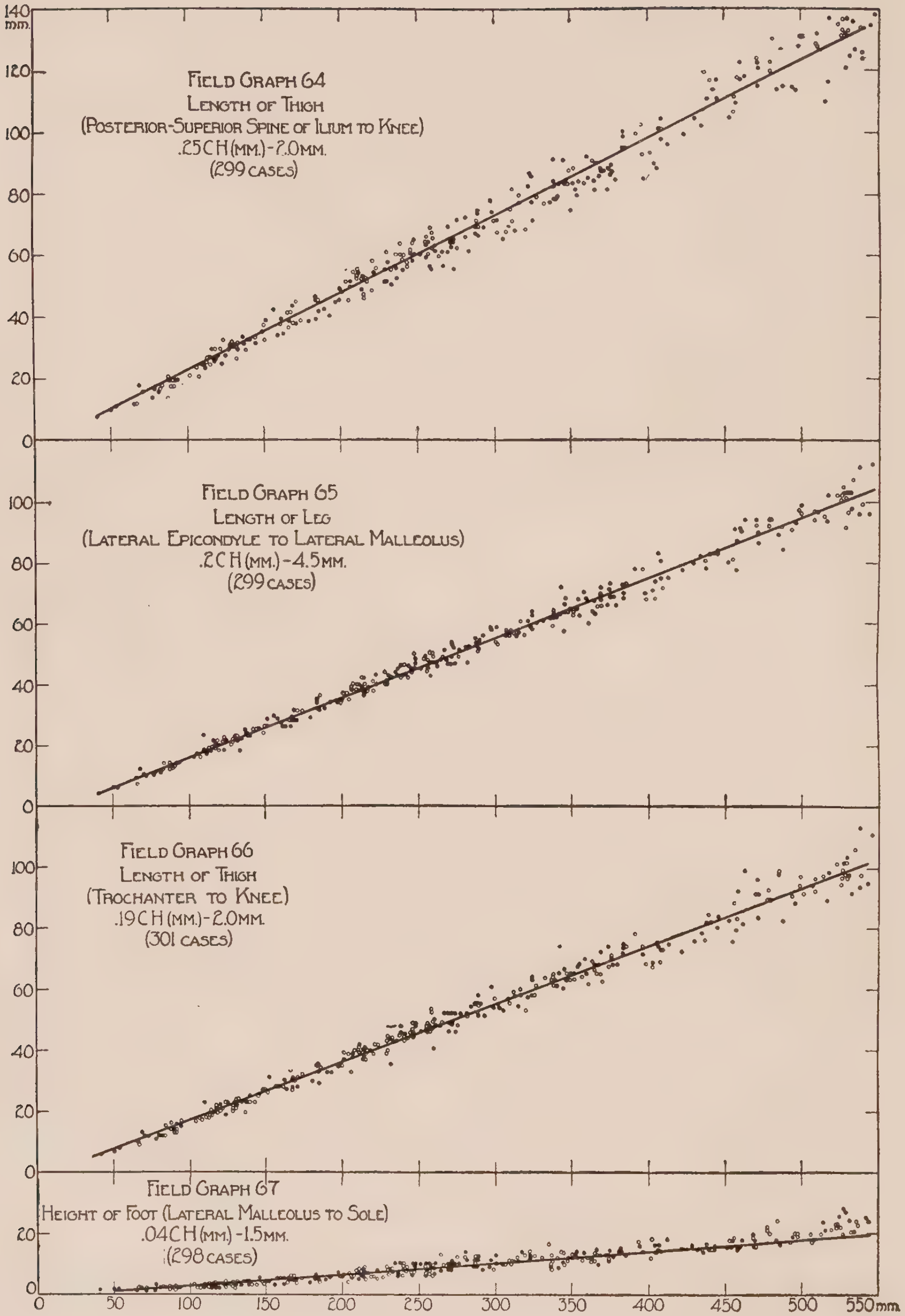
Field Graph 55
Length of Upper Extremity
.4 C H (mm.)-4.0 mm.
(314 cases)

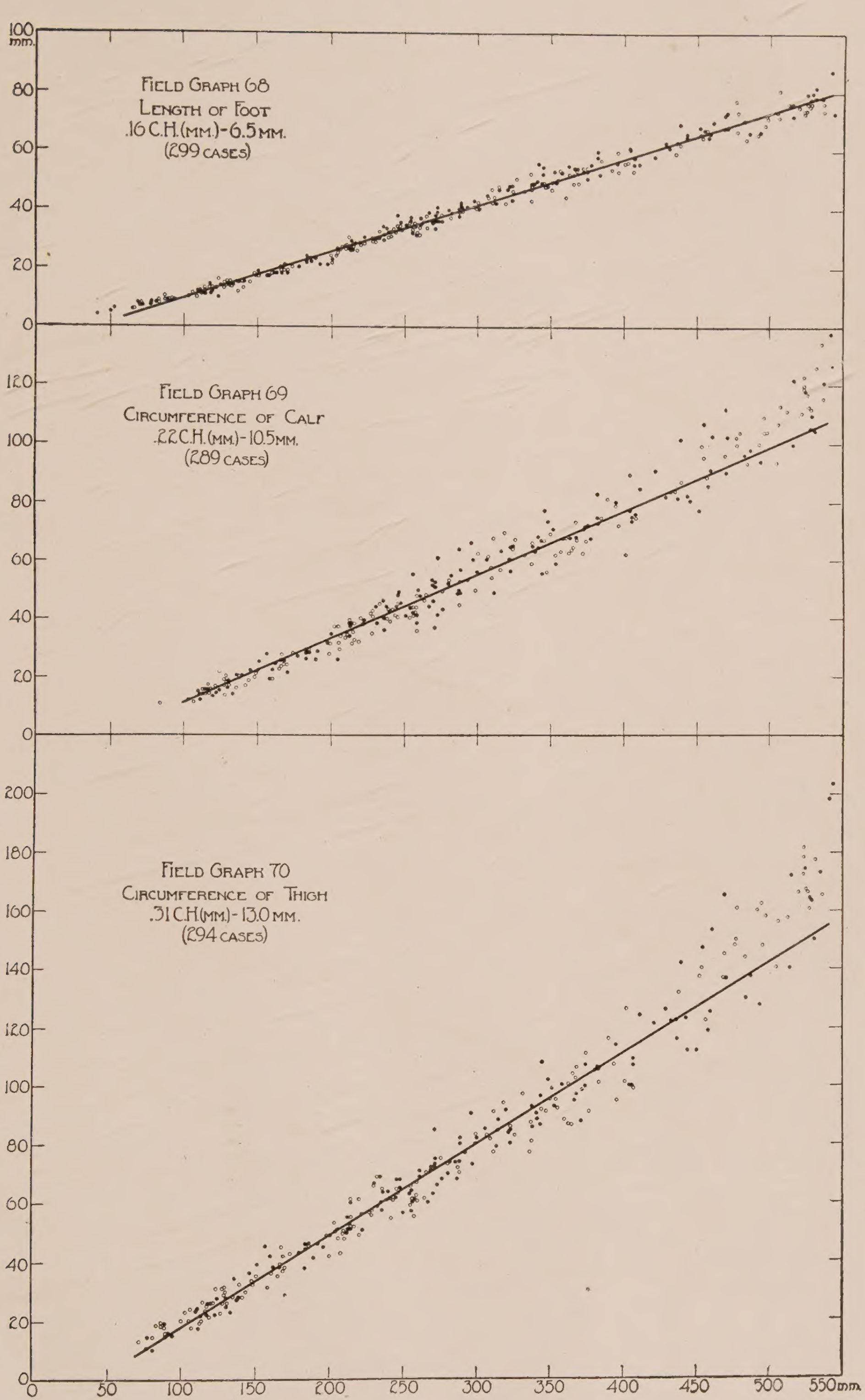


Field Graph 56
Length of Lower Extremity
.43 C H (mm.)-7.0 mm.
(315 cases)


100 mm.
80
60
40
20
0
Field Graph 57
Length of Arm (Acromion to Elbow)
.155 C.H.(mm.) - 0.5 mm.
(307 cases)
Field Graph 58
Length of Forearm
.13 C.H.(mm) - 1.5 mm.
(305 cases)
Field Graph 59
Length of Hand
.12 C.H.(mm.) - 3.0 mm.
(304 cases)
Field Graph 60
Length of Middle Finger
.075 C.H.(mm.) - 3.0 mm.
(292 cases)
0
50
100
150
200
250
300
350
400
450
500
550 mm


Field Graph 61
Circumference of Arm
.195 CH (mm) - 8.0 mm.
(294 cases)
Field Graph 62
Circumference of Forearm
.195 CH (mm) - 7.5 mm.
(290 cases)
Field Graph 63
Circumference of Wrist
.16 CH (mm.) - 8.5 mm.
(275 cases)
140 mm.
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
450
500
550 mm


140 mm.
120
100
80
60
40
20
0
Field Graph 64
Length of Thigh
(Posterior-Superior Spine of Ilium to Knee)
.25 C H (mm.) - 2.0 mm.
(299 cases)
Field Graph 65
Length of Leg
(Lateral Epicondyle to Lateral Malleolus)
.2 C H (mm.) - 4.5 mm.
(299 cases)
Field Graph 66
Length of Thigh
(Trochanter to Knee)
.19 C H (mm.) - 2.0 mm.
(301 cases)
Field Graph 67
Height of Foot (Lateral Malleolus to Sole)
.04 C H (mm.) - 1.5 mm.
(298 cases)
0
50
100
150
200
250
300
350
400
450
500
550 mm



Field Graph 68
Length of Foot
.16 C.H.(mm.)-6.5 mm.
(299 cases)

Field Graph 69
Circumference of Calf
.22 C.H.(mm.)-10.5 mm.
(289 cases)

Field Graph 70
Circumference of Thigh
.31 C.H.(mm.)-13.0 mm.
(294 cases)

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